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FRAMEWORKING FRUIT TREES[1]

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Frameworking of fruit trees is a relatively recent term to describe a comparatively new way of top grafting, new chiefly in the result rather than the detail of procedure in uniting scion and stock wood. The ordinary method of top grafting is well known and requires no description. Frameworking requires that practically the whole tree with limbs and branches down to one inch in diameter be refurnished with scion wood. This method of grafting is, however, applicable chiefly to trees which have reached full bearing. From the available literature reviewed by the authors it appears that the method was first devised by Messrs. F. and W. A. G. Walker of Lalla, Tasmania. The most extensive account of frameworking that has been reviewed is an article by Garner and Walker (1). In this publication the various details of procedure are discussed and the four methods of frameworking, stub grafting, side grafting, inverted L bark grafting, and awl grafting, are fully described, together with such matters as application of methods, costs and returns and materials used. Upshall (2) describes the frameworking method in a recent publication on orchard grafting. The purpose of this paper is to describe briefly the procedure used and the results obtained at the Dominion Experimental Station, Saanichton, B.C.

MATERIALS

The bulk of the grafting work done to date has been on mature pear trees of the Bosc, Dr. Jules Guyot, and Boussock varieties using Bartlett scions. The grafting has been done in early spring when buds have commenced to swell and show green but prior to opening of blossoms. Long scions with 7 to 9 buds have been used. Less extensive trials have involved Amanlis on Dr. Jules Guyot, and the Bachelier pear on stock wood of the Chinese variety Yak, which previously had been top grafted on Dr. Jules Guyot growing on a nursery root stock. Other preliminary trials have been made with apples and plums.

RESULTS

For a variety of reasons relatively little success has attended apple and plum frameworking but with apples there has been indication that satisfactory results can be expected, though it is doubtful if the frameworked tree will come into as good production the first year as in the case of pears. A considerable number of L side grafts have been made and

[1] Paper read before the Horticultural Group at the Annual Meeting of the Canadian Society of Technical Agriculturists at Toronto, Ontario, June 26 to 29, 1944, and revised to include yield data for the year 1944.
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satisfactory union has been obtained. A 28-year-old Duchess tree worked over to Merlin in 1943 showed effective union with 80% of the scion wood but there was very little fruit in 1944.

Limited trials with plums have not given as satisfactory results as with pears. A Sugar Prune, partly frameworked to Peach Plum in 1942 resulted in only 50% union of scion and stock. On the same tree using Mallard scion wood, results were a failure. The branch on which Mallard was worked lacked vigour. In 1944 scion wood of Michelson and Mallard worked on a vigorous tree of the Shropshire Damson variety has proved for practical purposes a failure both in regard to terminal bark grafts and L

FIGURE 1. Photographed March 30, 1940, immediately after frameworking. Note long scions for both side and end grafts. Tree 2 in Table 1.

side grafts. Over a long period of years a number of plum trees have at least in part been top grafted to other varieties with a considerable degree of success. Up to the present any recommendations as to results with apples and plums must be left in abeyance. Especially with plums, incompatability of stock and scion may be an important factory. In all frameworking it is, however, necessary to use only trees in a vigorous state of growth.

The first work with pear trees undertaken at this Station was commenced in 1939 by the junior author when a 25-year-old Dr. Jules Guyot pear tree was worked over to Bartlett. The method adopted at this time and followed since was to cut off all wood less than one-half inch in diameter, leaving nothing but a skeleton (See Figure 1). The L bark graft was adopted

FIGURE 2. Frameworked in 1940. Photographed in Feb. 1941. Tree 3 in Table 1.

for all side grafts and the ordinary bark graft for stubs of sufficient size. In the case of small stubs cleft grafting has been used, but when sufficient skeleton branches of large enough size for bark grafting are available the cleft method is not recommended. In 1940 another Dr. Jules Guyot was worked over, also a 25-year-old Bosc. In 1941 a third Dr. Jules was frameworked and in 1942 eight 28-year-old Boussock trees were frameworked and an equal number were top worked by standard methods. The 16 trees were in a single row and trees were alternated for the two grafting methods.

FIGURE 3. Frameworked in March, 1939. Photographed in Aug. 1940. Tree 1 in Table 1.

Table 1 gives results obtained from trees frameworked at this station, with yields prior to and subsequent to grafting.

TABLE 1.—TOTAL YIELD OF FRUIT FROM FRAMEWORKED PEAR TREES WITH BARTLETT SCIONS

Tree	Variety	No. of scions	Yield							
			1937	1938	1939	1940	1941	1942	1943	1944
			lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
1	Dr. Jules Guyot	125	137	9	Frame-worked	98	208	189	21	141
2	Bosc	112	271	356	157	Frame-worked	192	221	Out	Out
3	Dr. Jules Guyot	125	9	263	174	Frame-worked	162	258	4	243
4	Dr. Jules Guyot	106	15	229	171	176	Frame-worked	124	155	141
5	Boussock	132	—	365	136	474	48	Frame-worked	137	271

This table shows that one year after frameworking the trees came into commercial production. It further shows that after the second year of production, particularly in trees 1 and 3, that alternate bearing had again become established. Due to the position in which it was growing, tree 2 had to be taken out in the fall of 1942. Heavy fruiting the year after grafting has caused numerous branches to break but in no instance either from wind or weight of fruit have scions been broken out at the point of union.

The 8 Boussock trees grafted in 1942 had a lot of rough, tough old bark which is characteristic of mature trees of this variety. It appreciably increased the labour in making both the L and bark grafts. The number of trees involved in the trial made it possible to obtain more reliable data than had previously been obtained as to costs of frameworking and also permitted comparisons to top working. Table 2 gives the results obtained.

TABLE 2.—COMPARATIVE RESULTS OF FRAMEWORKING AND TOP WORKING PEAR TREES, 1942

——	Top worked by usual method	Frameworked
Kind of stock	Boussock	Boussock
Kind of scion	Bartlett	Bartlett
Number of trees grafted	8	8
Date of grafting	April 9-10	April 11-17
Total number of scions set	171	1060
Total hours required in grafting	28	90
Number of scions alive in June	171	950
Mortality in scions	0.0%	10.3%
Time required to remove branches	—	16 hrs.
Number of buds per scion	2-3	8-10
Time to remove suckers during 1942	0.75 hrs.	6.75 hrs.

The total cost for the 8 top worked and 8 frameworked trees was respectively $14.20 and $46.60. The cost in top working includes the final grafting operation in 1943. These figures are comparatively high due to the very hard bark on the Boussock variety and to the fact that a considerable amount of relatively inexperienced labour had to be used.

Table 3 presents yields and value of crop for 1943 and 1944 from frameworked and top worked Boussock trees using Bartlett scions.

TABLE 3.—PRODUCTION AND VALUE OF CROP (BARTLETT) FROM TREES GRAFTED IN APRIL, 1942

Method of grafting	Yield and grade		Value of crop	Total value of crop
	No. 1	No. 2		
	lb.	lb.	$	$
Top worked (8 trees)				
1943	88	0	2.64	—
1944	559	127	28.92	31.56
Frameworked (8 trees)				
1943	1098	0	32.94	—
1944	991	781	70.63	103.57

Grades as shown in Table 3 are based on size of fruit demanded for canning purposes. Size of fruit in 1943 for No. 1 grade was 2.00 inches and in 1944 the requirement for Grade 1 was 2.125 inches and 2.00 inches for Grade 2. The value of the crop is based on selling prices of $60.00 per ton for Grade 1 in 1943 and in 1944, $87.50 per ton for Grade 1 and $70.00 for Grade 2. All prices are f.o.b. cannery.

In topworked trees (8 trees in 1942) grafting costs were $14.20 for 8 trees and revenue $31.56 to the end of 1944. In frameworked trees (8 trees in 1942) grafting costs were $46.60 and revenue $103.57 for the same period.

CONCLUSIONS

From frameworking experiments conducted at this Station since 1936 the following conclusions may be drawn.

1. With apples, more evidence is needed to show that the extra cost of frameworking is justifiable.

2. With plums there is needed a considerable study to determine whether incompatibility of stock and scion is the limiting factor in successful frameworking and top working.

3. With pears, highly satisfactory results have been obtained and frameworking can be recommended. There has been no evidence of any incompatibility when using four different stocks with Bartlett scions, one stock with Bachelier scions and another with Amanlis scions.

4. Only trees in a vigorous healthy state should be used for any grafting.

ACKNOWLEDGMENT

The authors extend their thanks to Mr. F. A. Maxwell, orchard foreman at this address for his keen interest and accurate records in carrying out the various grafting and harvesting operations.

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PROMISING NEW METHODS USED IN PROPAGATION OF HYACINTHS[1]

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Any method that will shorten the time required to produce large sized flowering bulbs of hyacinths or that will facilitate their propagation is of special value in view of their slow natural increase. It is the purpose of this paper to describe three new or little known methods and practices that have a bearing on these points. The methods described are: (1) the Saanichton system of propagation, (2) the production of hyacinth bulbs from discarded basal plates, and (3) scaling the bulbs after incubation. Reference is made to the standard system of hyacinth propagation as it relates to the contents of this paper. This is not described because it is generally well known to hyacinth propagators.

HISTORY

The Saanichton system of propagation is based on the results of experiments conducted at the Dominion Experimental Station at Saanichton. B.C. The original experiments were begun prior to 1916. Among other things demonstrated by these early experiments was that callusing freshly cut hyacinth bulbs could be achieved under moist conditions without impairing bulblet formation. Thus, the dry phase of callusing was omitted resulting in the period for callusing and that for incubation commencing simultaneously. This procedure is opposed to the generally accepted practice which stipulates that freshly cut bulbs should first be callused under dry conditions for a period of 2 to 3 weeks before they can be safely incubated under moist conditions (3), (9). Other experiments have shown that under Saanichton conditions, the dry period of callusing has an adverse effect which increases with the rise in temperature and the duration of the exposure. (8). Results from these experiments, which warrant omitting the dry callusing period under Saanichton conditions, form the basis for the system described. Additional data are needed before the Saanichton system can be widely accepted, and experimental work along these lines is being continued.

The planting of basal plates has been done by at least two other propagators. Generally, however, this means of propagation appears to have been overlooked. From the literature available there are no data on the subject.

Scaling, which is separating the scales after incubation so as to leave a piece of the parent scale attached to each bulblet, is not a usual practice. This method is not mentioned in the literature and is relatively new. On the other hand, scaling before incubation is not uncommon. In 1935, Luyten (4) described a similar method in which scaling was done before incubation. The material used in this case was Hippeastrums. Although scaling as outlined in this paper has not been tried by the author, it has been carried out successfully by a hyacinth propagator for several years on Vancouver Island.

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[1] Paper read before the Horticultural Group at the Annual Meeting of the Canadian Society of Technical Agriculturists at Toronto, Ontario, June 26 to 29, 1944.

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MATERIALS AND METHODS

The Saanichton system of propagation as well as the standard method requires that there be a high degree of control of temperature and humidity during the incubation period. For this purpose there is used a specially built cabinet with thermostatic heat control (Figure 1). It is provided with a fan to equalize temperature which is held at 26.7° C. throughout the propagation period. Heat is generated by a 100-watt Mazda lamp.

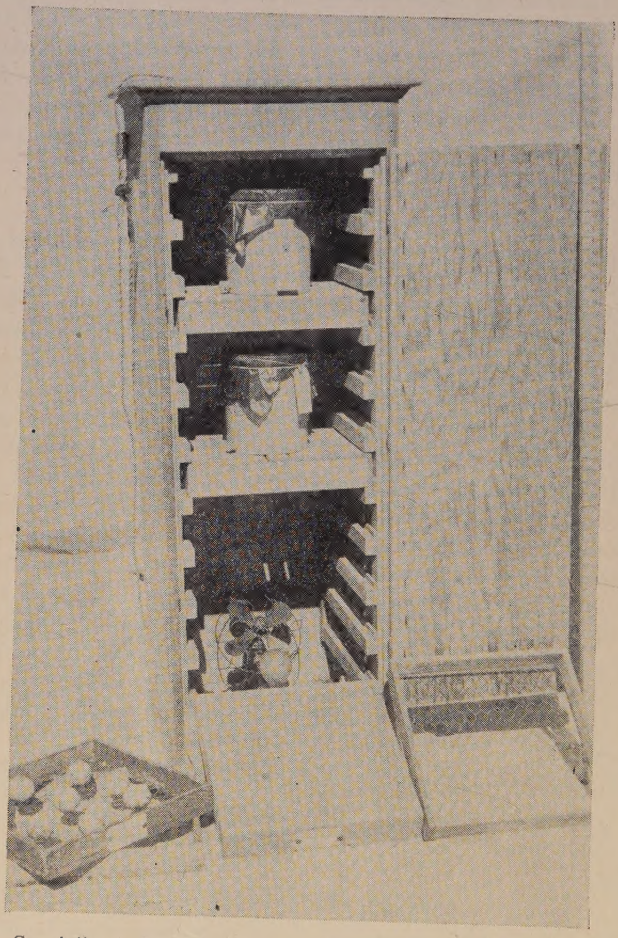

FIGURE 1. Specially built cabinet used for incubating hyacinth bulbs in the Saanichton system of propagation. The scooped bulbs are placed in gallon crocks containing moist sphagnum peat moss. The crocks are sealed with wax paper to retain the moisture in the peat. A 100-watt Mazda lamp generates the heat which is distributed by an electric fan and controlled by a thermostat. The figure also shows scooped bulbs on screen trays. When this method is used, a solid bottom tray is filled with dampened sand. The sand is kept moist during the entire incubating period.

The procedure followed in the Saanichton system is similar to the standard method but with one important exception. In the Saanichton system the dry period of callusing has been omitted. Instead, the freshly cut bulbs are placed directly into moist sphagnum peat moss, or a mixture

of moist sand and peat, and incubation started immediately. To maintain the proper level of humidity the bulbs and peat are placed in a crock or container and covered with a lid consisting of a piece of wax paper held in place with an elastic band. A suitable level of moisture when using peat alone is approximately 230% on a dry weight basis. During the period of incubation the container with its contents is left in the cabinet. Incubation is completed about October or early November. By this time the bulblets have developed sufficiently for planting. For planting, the bulblets are left attached to the mother bulbs.

Bulbs measuring 16 to 20 centimeters in circumference with thick fleshy scales and no attached offsets are used for cutting. The bulbs are cut with a sharp budding knife (Figure 2). The scooping method of cutting is used in preference to scoring or coring. This is done when the bulbs are fully ripened, which is usually in July.

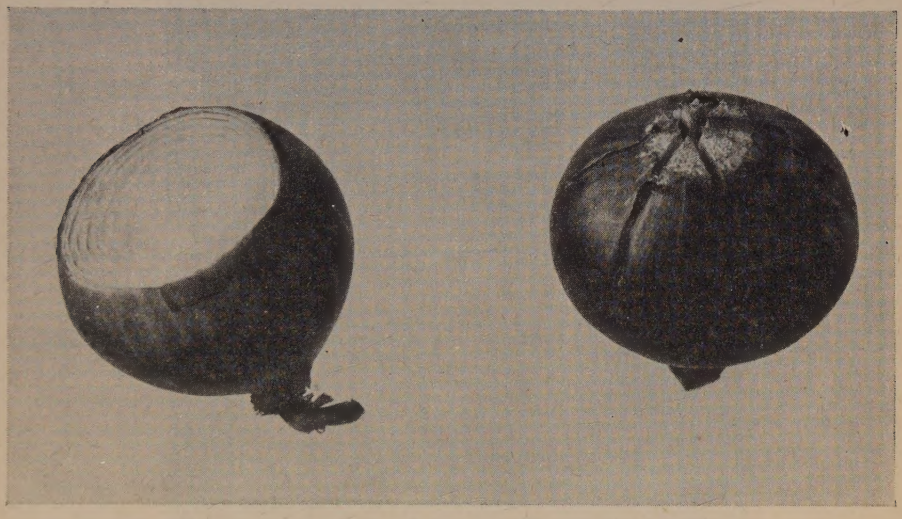

FIGURE 2. The scooping (right) and scoring method of propagating hyacinth bulbs as illustrated on onions. The former method produces a large number of small bulblets; the latter yields fewer but the average size is larger.

Fairly satisfactory substitutes for the controlled temperature cabinet have also been used. These include a glass covered cold frame and a greenhouse propagating frame where the only source of heat is the sun. Another type makes use of an oil lamp which more or less controls the temperature. Types which give the greatest temperature control are most satisfactory.

The only material required when propagating from basal plates is a container filled with moist peat as already described under the Saanichton system. The procedure followed with basal plates which are obtained from scooped bulbs is to place the plates immediately into the containers with the peat. The most suitable temperatures for the storage of the basal plates while in the peat have not been determined but the fluctuating temperatures in a greenhouse propagating frame seem satisfactory. In November the plates are planted outdoors.

The materials required when scaling scooped bulbs are large sized greenhouse flats, a quantity of rich compost, some sand and a basement or room where the temperature is between 10° and 15° C. The procedure now followed is to remove for planting each bulblet with a piece of the parent scale attached after incubation is completed. This is in contrast to the standard method in which the scooped bulbs are planted intact. The bulblets are planted in the flats which contain a lower layer of compost and an upper layer of sand. The base of the bulblet is planted so that it rests in the sand layer and just above the compost. Sand is screened over the bulblets so that the final covering is about $1\frac{1}{2}$ inches deep. The flats are kept in a basement until top growth appears, after which they are transferred outdoors. This takes place usually after the New Year. The bulblets grow in the flats for one season. When they have ripened they are harvested and reset in the ground in nursery rows. (Figure 3).

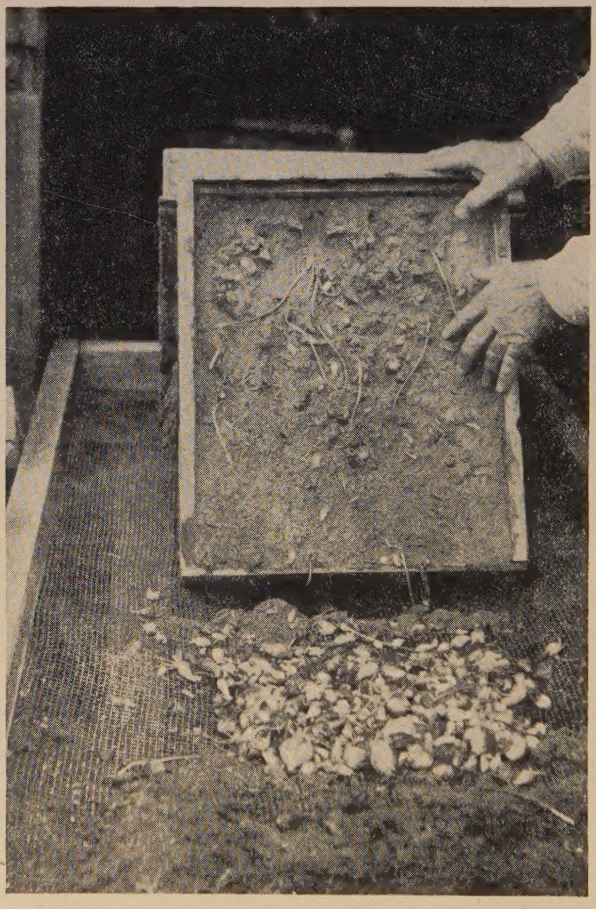

FIGURE 3. Harvesting 1-year-old hyacinth bulblets raised from scooped bulbs which were scaled after incubation. Each bulblet was planted individually with a piece of attached scale removed from the scooped parent bulb. Planting was done in greenhouse flats. The flats were left in a cool basement until top growth appeared after which they were transferred outside. The above figure illustrates the method of separating the bulblets and compost after the tops had ripened off in July.

RESULTS

Results from the Saanichton system have been fairly satisfactory. The peat provided a cheap and effective means for maintaining a suitable level of humidity. It was also effective in eliminating or reducing moulds and storage rots during incubation to a point where they were relatively unimportant. For these reasons routine inspections were reduced from several to one or two resulting in a saving of time. Placing the freshly cut bulbs immediately into the moist peat eliminated the separate and additional operation of callusing under dry conditions.

Planting basal plates in November, 1942, showed that 30% of the bulbs harvested after the first season measured 8 centimeters or more in circumference. The largest bulb measured 13 centimeters and two offsets were attached. In another experiment from planting basal plates in 1943, 97% produced satisfactory plants. Of these, 52% produced flowering spikes, the majority of which had between 10 and 20 medium sized florets each.

Results from scaling indicate that a saving of one year was obtained.

DISCUSSION

The Saanichton system offers certain advantages that the standard system does not. This advantage is chiefly a saving in time as a result of: (1) the elimination of the dry callusing operation considered essential in the standard method, (2) the reduction in the number of routine inspections necessary to maintain a level of humidity in keeping with healthy storage conditions. The cheap and effective means for maintaining humidity which is provided by the peat is also an important advantage. Control of humidity is usually a problem left to the judgment of the propagator unless special apparatus is installed. Though yields from the Saanichton system have not quite equalled those recorded as average elsewhere (3, 9), evidence indicates that this may be satisfactorily overcome. Experiments along this line are continuing.

The results from planting basal plates show that this method of propagation is satisfactory from the standpoint of bulb production. Propagators are thus given another means of increasing their stocks. Compared with the scoring practice, propagation from basal plates rates as a quicker method of producing larger sized bulbs though the quantity is considerably less.

In regard to the time saved as a result of scaling bulbs after incubation this advantage is evidently the result of the optimal spacing allotted to each bulblet. Time consumed in scaling is not excessive. It is possible, however, that this may be a limiting factor where mass production is carried on. At present, scaling would appear to merit more extensive use.

SUMMARY

1. Three new methods of hyacinth propagation are described. These are: (a) the Saanichton system, (b) planting basal plates, (c) scaling scooped bulbs after incubation.

2. The Saanichton system introduces a different aspect to the commonly accepted idea that dry callusing is a prerequisite to the incubation phase of propagation. The new system omits the dry phase and in its place moist peat is substituted.

3. Advantages offered by the Saanichton system are: (a) saving in time required during propagation, (b) a cheap and effective means for maintaining humidity.

4. The propagation from basal plates which were heretofore discarded is considered a satisfactory new method of increasing hyacinth stocks.

5. Scaling of scooped bulbs after incubation indicates a saving of one year in the time required to produce large sized flowering bulbs.

ACKNOWLEDGMENT

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ANALYSIS OF HORTICULTURAL SOILS[1]

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The use of rapid methods of soil analysis was begun in the Department of Horticulture, Ontario Agricultural College in 1937 at the request of some commercial florists. At that time much publicity was being given to such methods of analysis in trade papers, perhaps causing undue optimism among growers that a "cure-all" had been discovered. This phase was followed by many disappointments, but as enough growers remained interested the work was continued.

Spurway (1) procedures were used because his extracting solution for the more readily available substances was found to be admirably suited to the high nutrient levels usually found in greenhouse soils. Records of analyses were noted as parts per million and growers were soon using the term "p.p.m" intelligently. The analyses were based on the soil extract.

Each sample of soil was tested for active (readily available) nitrogen as N in the NO_3 form, potassium as K, phosphorus as P, calcium as Ca, magnesium as Mg, sulphates as SO_4 and chlorides as Cl. Reserve tests were made for phosphorus, potassium, iron and manganese. The total soluble salts was determined by the use of a resistance machine, and pH by means of either Bromothymolblue or in the case of muck and peat soil by means of a glass electrode potentiometer.

GREENHOUSE SOILS

(a) Ornamentals

There are comparatively few persons in Ontario who grow ornamentals under glass extensively and thus it was possible to establish and maintain good contact with the industry throughout the developmental phases of the work. The growers themselves had important unsolved production problems which were readily seen by them because of the nature of their business. Good co-operation was received from the growers and in no small measure was responsible for the successful development of the project. Their records were reliable and any soil manipulation such as the addition of fertilizer was carefully done.

The general procedure in the attempt to determine suitable nutrient levels for the various crops was as follows. The grower sent in soil samples from specific crops at regular intervals during the growth of the crops. Each set of analyses was accompanied by suggested soil treatments, and visits were made regularly to study the effect on the crops of the suggested treatments. A complete history of each bench in each greenhouse was kept over a period of years. Eventually it was possible to determine by comparison from the accumulated data the approximate optimal levels of nutrients for each crop. Now nearly all of the larger greenhouse establishments make full use of quick soil analyses as part of their regular practice and many of them have established laboratory facilities of their own.

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[1] Paper read at the Horticultural Group meetings of the Canadian Society of Technical Agriculturists at the Annual Meeting at Toronto, Ontario, June 26-29, 1944.

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The chief results obtained have been control of the type of growth required for a given variety of plant at the different growing phases, important savings in the amounts of fertilizers used, the virtual elimination of toxic accumulations of nutrient materials, and it has been possible with the help of sterilization and leaching to use the same soil more or less indefinitely and thus eliminate the tedious and expensive job of frequent soil changes.

The principal crops grown were, and are, roses, carnations, chrysanthemums, and snapdragons. The nutrient levels best suited for the production of roses in Ontario were found to be very similar to those recommended by American investigators, i.e. nitrate nitrogen 20-25 p.p.m.; phosphorus 8-12 p.p.m.; potassium 20-30 p.p.m. Chrysanthemum levels were found to vary considerably with varieties. Some varieties which are slow growers, with small hard foliage, needed nitrate nitrogen levels of 10-12 p.p.m., whereas the vegetative varieties needed comparatively low nitrogen levels, ranging from trace to 5 p.p.m. Chrysanthemum requirements for phosphorus and potassium were similar to those for roses. Carnations differed from roses and chrysanthemums in that they needed a phosphorus level of at least 12-16 p.p.m. Snapdragons were found to respond best to very low nitrogen levels of trace to 3 p.p.m. of nitrate nitrogen; 8-12 p.p.m. of phosphorus and 15-20 p.p.m. potassium. Apart from the various levels of nitrogen, phosphorus, potassium, calcium, etc., the Spurway test for sulphates and chlorides has been invaluable in preventing the accumulation of these residue salts in toxic quantities.

(b) Vegetables

A survey is being made of greenhouse soils producing vegetables and the method used in an attempt to determine the approximate optimal nutrient levels is similar to that described above for ornamentals. Travel restriction has curtailed the number of districts included in the survey but 26 commercial houses are being visited regularly. It is not possible at this time to give definite data, but there are reasonably well founded indications concerning good nutrient levels for the two major crops, cucumbers and tomatoes. Nitrogen levels varied over a wide range from 5-20 p.p.m. with satisfactory results and it would appear that from 5-10 p.p.m. nitrogen is sufficient. Active phosphorus 16 p.p.m. and active potassium 30-40 p.p.m. seem to be adequate.

INTENSIVELY CULTIVATED VEGETABLE SOILS

(a) Upland

The number of vegetable growers runs to thousands, and the procedure used in an attempt to determine approximate optimal nutrient levels was of necessity somewhat different from that used in the study of greenhouse soils. It was realized, too, that the problem of outdoor crops was much more complex in that an infinite number of soil variations occur, methods of husbandry vary greatly and environmental conditions cannot be controlled as under glass. A survey was made in 1941 with the areas to be studied selected more or less at random. Thirty-four growers in eight districts were chosen, and each was visited at approximately fortnightly intervals during the growing season with the purpose of collecting soil samples and making observations on any factors other than nutrition

which might influence the yield of the crop being studied. Successive analyses from each field were characterized by either the maintenance of levels for each element or by uniform drifts. Nitrogen was the exception in that it fluctuated frequently and rather widely. The crops were graded as Good, Fair, and Poor and an attempt was made to assess the effect on the grading of such factors as drought and pests. The complete data are to be found in a bulletin (2) published in 1942. We believe that the data warrant the assumptions indicated in the following table for the crops studied. Those crops included: beets, cabbage, carrots, cauliflower, head lettuce, onions, tomatoes, asparagus, egg-plant, radish, sweet pepper, parsnips, and celery.

TABLE 1.—NUTRIENT LEVELS FOR UPLAND SOILS IN RELATION TO TRUCK CROP PRODUCTION IN SOUTHERN ONTARIO

Nitrogen in p.p.m.		Phosphorus in p.p.m.		Potassium in p.p.m.		
Average	Range	Available	Reserve	Available	Reserve	
4+	Trace to 20	12+	20+	20+	50+	Adequate
2	Trace to 6	6	12	10	20	Marginal
		Below the above levels				Deficient

The co-operation of the Ontario Women's Institute Branch and the members of their "Girls' Garden Brigade" made it possible to get soil samples from 682 farm gardens scattered widely over the province, and because these gardens were judged in competition it was possible to obtain information on the crop behaviour. Probably the results cover a fair cross section of the gardens producing vegetables on a non-commercial basis and a summary of the nitrogen, phosphorus, potassium and pH levels are given in the following table.

Summary of Results of Survey of Girls' Garden Brigade Soils

Nitrogen	54% low to very low	(zero to 1 p.p.m.)
	7% high	(6 p.p.m. and up)
Phosphorus	52% very low	(active and reserve)
	4% high	(8 p.p.m. and up, active)
Potassium	50% very low	(active and reserve)
	7% high	(20 p.p.m. and up, active)

5.5% had a pH of 6.0 or lower.

(b) Peat and Muck

Two of the larger muck areas, Thedford Marsh and Bradford Marsh, have been under investigation for the past 4 years and the Erieau Marsh during the past year. This type of soil presents rather a peculiar problem in that the nutrient levels are considerably lower than those found on upland soils. This is especially true of the Thedford and Bradford Marshes. Despite heavy applications of fertilizer, particularly those of high potash

analysis, nutrient levels of nitrogen trace-2 p.p.m., phosphorus 2-5 p.p.m., and potassium trace-10 p.p.m., are found producing excellent crops. No explanation is offered for this phenomenon at the present time. This is not so true of the Erieau Marsh. The nutrient levels in this particular area are quite comparable to some of our upland market garden areas. This project is still under investigation and the work carried on in the Erieau Marsh is being done in co-operation with the Western Ontario Experiment Station at Ridgetown and the Department of Chemistry here.

SUMMARY

The use of rapid methods of soil analysis is now firmly established in greenhouses devoted to the production of florist crops and there is every reason to believe that it will become standard practice in greenhouses in which vegetables are grown. When sufficient cognizance is taken of factors, other than soil nutrients, which may affect vegetables grown intensively in upland soils, and when it is remembered that there are often hidden factors affecting such crops, it has been demonstrated that soil analyses are definitely useful in the production of vegetable crops.

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SOIL NITRATES UNDER VARIOUS FERTILIZATION AND GREEN-MANURE CROPPING SYSTEMS[1]

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A very important element in the nutrition of fruit trees is nitrogen, a deficiency of which results in poor growth and fruiting, and an excess, in susceptibility to disease and winter injury. It is becoming generally recognized that available nitrogen should be in good supply in the soil during the spring and early summer to stimulate good growth, but by July should be nearly exhausted so that growth may cease. Stoppage of growth at this time is desirable to permit the accumulation of carbohydrates necessary for good fruit colour and satisfactory wood maturity.

The maintenance of soil organic matter in orchards is causing some concern to growers. In non-sod orchards a shortening of the early-season cultivation period permits a longer season for growing green-manure crops and a consequent increase in dry matter to be incorporated with the soil. Farm manure is being added to many orchards and some growers are using straw and old hay. Little is known about the effects of these treatments on soil nitrates except that the incorporation of dry matter, itself low in nitrogen, may result in nitrogen starvation of companion or succeeding crop.

PLAN AND PROCEDURE

A comprehensive experiment on the maintenance of soil organic matter was commenced in 1936 at the Ontario Horticultural Experiment Station. Small plots on a fine sandy loam soil were planted to various annual crops commonly used as green manures in orchards. Each crop plot was divided into three sections for differential commercial fertilizer treatment: a, unfertilized; b, 400 lb. 0-12-15 fertilizer per acre per year (PK); c, same as b plus 300 lb. sulphate of ammonia per acre per year (NPK). Each section was 36 feet by 8 feet, approximately 1/150 of an acre.

Five buckwheat plots were given the following annual applications: 1, farm manure, 10 tons per acre; 2, legume hay, 3 tons per acre; 3, straw, 3 tons per acre; 4 and 5, half-rate combinations of straw with the other two materials. In dry matter 3 tons of hay and 3 tons of straw are each approximately equivalent to 10 tons of farm manure. All fertilization, both organic and inorganic, was done about the middle of May, a few days before the green-manure crop was seeded.

Each crop-fertilizer treatment was in duplicate, occurring in A and B Series. Samples for nitrate determinations were taken from the b (PK) and c (NPK) sections of certain plots in A Series only. Each soil sample was a composite of three borings or diggings in the top 6 inches of each section. Tests were made about every two weeks from mid-May to late September. Nitrates were determined immediately by the phenoldisulphonic acid method and the results were calculated as parts per million on the oven-dry weight basis.

[1] Paper read at the Horticulture Group meetings of the Canadian Society of Technical Agriculturists at at the Annual Meeting at Toronto, Ontario, June 26-29, 1944.
[2] Chief in Research.
[3] Assistant in Research.
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RESULTS

The Accumulation of Soil Nitrates under a Buckwheat Green-manure Crop, as affected by Applications of Farm Manure, Straw, and Legume Hay

(a) Without added nitrogen (PK)

Legume hay alone gave the highest average nitrate readings and, except at the beginning of the season, straw alone gave the lowest readings (Figure 1). There was little difference between the manure treatment

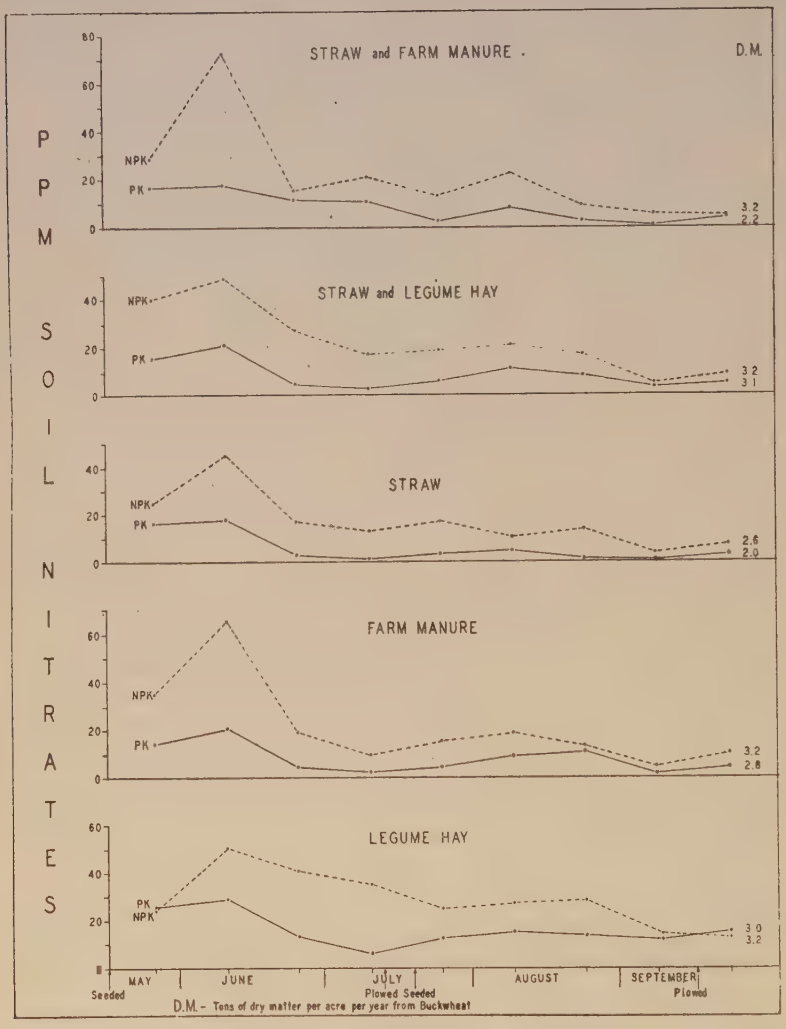

FIGURE 1. Soil Nitrates, 1937-41, under buckwheat green-manure crop, two per year, as affected by annual applications of farm manure, straw, and hay, both with and without added nitrogen.

and the straw-hay and straw-manure combinations, though the latter tended to be slightly lower in the latter part of the season. Straw, used singly, depressed the yield of buckwheat and there was only slight improvement with the straw-manure combination but the straw-hay combination

gave yields in line with legume hay, and with manure. The decomposition of the straw, a low-nitrogen material, tended to keep the soil nitrates relatively low throughout the growing season but at the beginning of the next season, soil nitrates were as high in this plot as in any of the others except the legume hay plot.

(b) With added nitrogen (NPK).

Almost without exception, the addition of 300 lb. per acre of sulphate of ammonia in mid-May increased the soil nitrates *throughout the whole season* (Figure 1), even though the greater growth of buckwheat stimulated thereby probably resulted in greater nitrogen usage. The addition of nitrogen to the straw plots increased the soil nitrates above the non-nitrogen plots of the other treatments, and yet high yields of dry matter

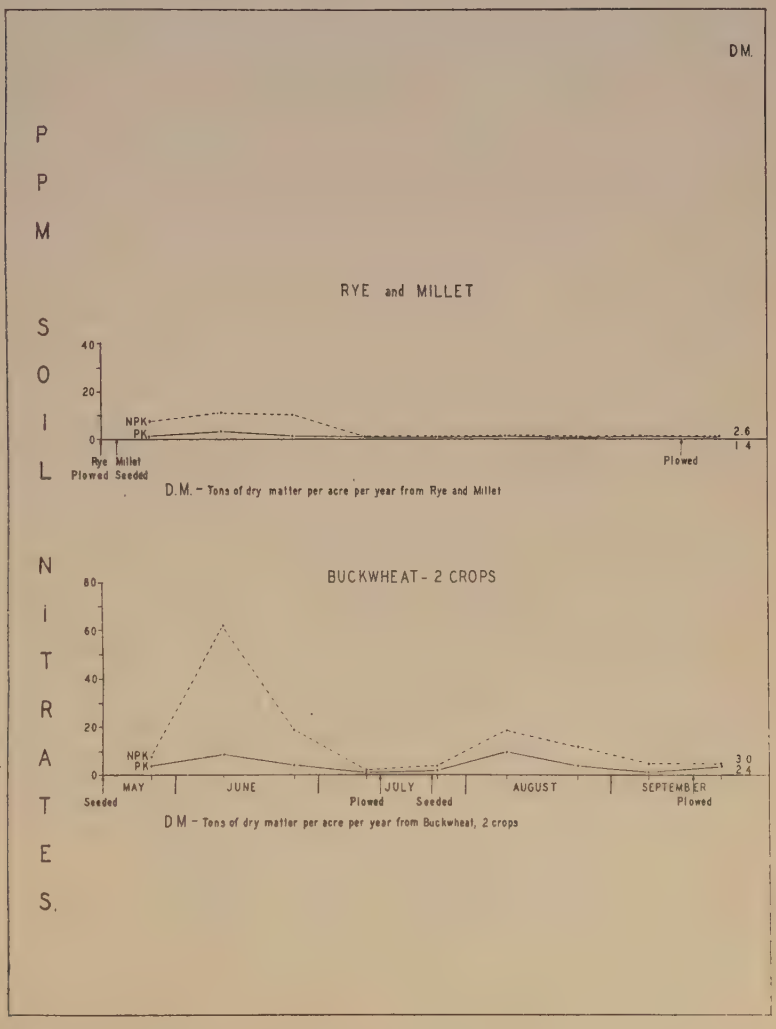

FIGURE 2. Soil nitrates, 1940-42, under buckwheat, and rye-millet green-manure crop, both with and without added nitrogen.

did not follow. There is a suggestion therefore that factors other than nitrogen limitation operate against the growth of buckwheat when straw is used by itself.

The Accumulation of Soil Nitrates under Buckwheat, and Rye-millet Green-manure Crops

The comparison is between buckwheat two crops per year, and the rye-millet combination (Figure 2). Rye was sown in the fall, plowed under in the spring before heading, and millet was planted a few days later. While buckwheat left a reserve of nitrates in the soil the millet crop very soon reduced the nitrate supply to 1 p.p.m. or less and kept it there throughout the balance of the season. The addition of 300 lb. per

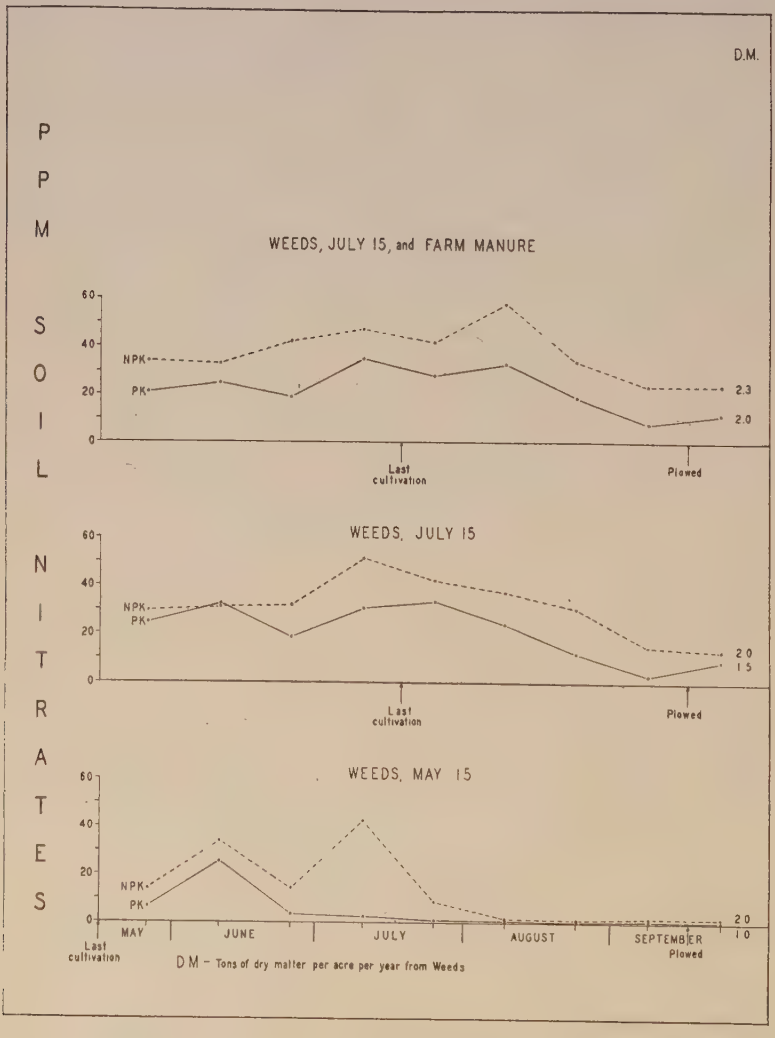

FIGURE 3. Soil nitrates, 1938-41, under weed green-manure crop from May 15 and July 15, the latter with and without farm manure and all three treatments with and without added nitrogen.

acre of sulphate of ammonia merely delayed for about two weeks the almost complete usage of nitrate though it did result in almost doubling the amount of dry matter obtained from the tops of the plants.

The Accumulation of Soil Nitrates under Weed Green-manure Crops with and without Farm Manure

When weeds were allowed to grow from mid-May onwards the soil nitrates were soon reduced to a low level (Figure 3) and nitrogen starvation symptoms appeared on the section which had received no sulphate of ammonia. The result was a yield of only 1 ton of dry matter per acre per year. Yellow foxtail, barnyard grass and old witch grass made up a high proportion of the weeds. The application of sulphate of ammonia to the adjoining section kept the nitrate supply higher throughout the season, gave a small proportion of lamb's quarters and pigweed, and doubled the yield of dry matter. However, even in this section the nitrates were reduced to about 2 p.p.m. from early August onwards.

Weeds allowed to grow from mid-July were of different species, mostly lamb's quarters and pigweed. These weeds did not show nitrogen starvation symptoms and, on the PK section gave a yield of dry matter of 1.5 tons per acre per year, a 50% increase over the weeds which started growing two months ahead of them. With nitrogen fertilization (NPK) the dry matter rose to 2 tons per acre per year, the same as the comparable section on which the weeds started two months earlier.

There was also a weed plot which received spring applications of 10 tons of farm manure per acre and on which the weeds are allowed to grow after mid-July. The weed population on this plot was similar to that on the comparable unmanured plot but reached somewhat higher amounts of dry matter (Figure 3). In the early part of the season there was not much difference in nitrates but later, the manured plot gave slightly higher readings.

DISCUSSION

In so far as the nitrate supply under a buckwheat green-manure crop is concerned there appears to be justification for using either legume hay or a mixture of straw and legume hay equal parts, as substitutes for farm manure whenever the cost of straw and hay compares favourably with farm manure. When no nitrogen was applied, half-rate applications of straw and farm manure seemed to be slightly less desirable than legume hay, and its mixture with straw both in nitrate accumulation and yield of dry matter. However, when nitrogen was added in the spring, the yield of dry matter in the buckwheat was equal to the other treatments, and nitrate accumulation in the top soil was very similar to them.

Millet, and weeds of the grass family allowed to grow after mid-May, kept the nitrates at a very low level. With millet, nitrates were reduced to 1 p.p.m. in about one month, and with weeds of the grass family, in about two months. On the sections where nitrogen was added, nitrates reached this low point about two weeks later in each case. It appears therefore that nitrogen starvation of the trees might result in orchards

where millet is sown about mid-May or weeds allowed to grow from that time. Instances of this condition have been seen in Experiment Station orchards and elsewhere in the Niagara District.

Buckwheat is probably a much safer green-manure crop to use where cultivation is being discontinued about the middle of May. For a green-manure crop starting in July, when the flush of tree growth is over, millet or weeds would probably be quite satisfactory. They might in fact be the best green-manure crops on rich soil where fruit colour is poor and winter injury a problem. However, if they are being followed by a crop of winter rye an application of quickly available nitrogen would be required for the best growth of the rye.

SUMMARY

1. Judged on the basis of dry matter of buckwheat as a green-manure crop and nitrate accumulation under that crop, either legume hay or straw or combinations of the two were satisfactory substitutes for farm manure. A combination of farm manure and straw was somewhat less satisfactory, and where straw was used by itself, even with adequate nitrogen, the growth of buckwheat was depressed.

2. Under buckwheat there was an almost continuous reserve of nitrate, whereas under millet, and weeds of the grass family, starting in mid-May, the nitrates were soon reduced to negligible amounts.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of the following students who, in the various years, took most of the nitrate readings: L. R. Webber, O. J. Phelan, K. Marsh, H. J. O'Reilly, and R. Morris.

HISTOLOGICAL OBSERVATIONS ON THE LOCATION OF PIGMENTS IN THE AKENE WALL OF THE SUNFLOWER (*HELIANTHUS ANNUUS L.*)[1]

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[Received for publication December 11, 1944]

Observations of the sunflower fruit, botanically an akene, but commonly referred to as a seed, show that it has three layers which may develop pigment independently of each other (5). The outer layer is the epidermis which may be entirely free of pigment or possess striped patterns of either dark brown or black colour. Below this appears a corky layer which may be either non-pigmented or solidly coloured with a purple pigment. Between the corky layer and the rigid portion of the fruit a solidly black or brown coloured layer is often found. No pigment, pigment in any one layer, or any combination of the pigments in these different regions may occur.

The purpose of the study herein reported was to determine the origin of these pigments in relation to the development of the ovary wall and their location in the mature fruit.

MATERIALS AND METHODS

Mature fruits from lines showing no pigment, striped pattern only, pigment in all three regions, and purple pigment of the corky layer and a striped pattern were studied. For the study of the development of the ovary wall and the pigment, a line having the innermost pigment layer and the striped pattern was used. Collections from this line were made during the summer of 1941 from plants varying in age from those in which the inflorescence initials were only about $\frac{1}{4}$ inch in diameter, to those with mature fruits. Bracts were removed from the earlier stages and then a portion of the involucre was fixed. In later stages several individual fruits were taken.

A form-acetic-alcohol solution consisting of 380 cc. of 70% ethyl alcohol, 10 cc. of glacial acetic acid, and 22 cc. of formalin (i.e. 40% or commercial formaldehyde) was used for fixing and storing.

Immediately after collection and immersion in the fixing agent the material was subjected to a vacuum, created by a tapwater suction pump, for 1 to 2 hours. The decrease in volume following this treatment was made up with 70% ethyl alcohol.

Ethyl alcohol was used for dehydration. After reaching 100% alcohol, the material was allowed to remain in it for 24 hours and then passed through a xylol-alcohol series consisting of $2\frac{1}{2}$, 5, 10, 15, 25, 50, 75 and 100% xylol. Stages up to 4 days after flowering required about 80 hours and later stages about 140 hours for the complete series.

Because of the rigid nature of the later stages a rubber-beeswax-paraffin mixture (3) was chosen for embedding to facilitate sectioning. The mixture consisted of 100 grams of parowax, 4 to 5 grams of rubber-

[1] A summary of studies conducted under the direction of Dr. C. R. Burnham, Department of Agronomy and Plant Genetics, University Farm, St. Paul, Minnesota.

[2] Formerly Agricultural Assistant, Dominion Forage Crops Laboratory, Saskatoon, Saskatchewan, now temporary Extension Assistant, Poultry Department, Ontario Agricultural College, Guelph, Ontario.

paraffin stock mixture and 1 gram of beeswax. The rubber-paraffin stock mixture was prepared by dissolving 20 grams of raw rubber in 100 grams of smoking hot paraffin. Preparation for embedding required about 55 hours for the earlier stages and 100 hours for the later stages.

Sections were cut with a rotary microtome at 12.5 microns in the earlier stages and 17.5 and 20 microns for the later stages. Acid fuchsin (1% in 70% ethyl alcohol) was used for staining.

OBSERVATIONS

Cross, radial and tangential sections with reference to the individual ovary or fruit are discussed. Unless otherwise indicated, the statements in this section refer to fruits possessing the inner layer of pigment and the striped pattern, but no purple colour.

The earliest stage examined, which was about two weeks prior to flowering, showed the ovary wall as a mass of parenchymatous tissues with the exception of the outer single layer of epidermal cells. Approximately 4 days before flowering the ovary wall exhibited a characteristic structure as shown in the cross section of Figure 1. Under the epidermis a single layer of cells was clearly differentiated. A row of vascular bundles was evident. Numerous ray-like structures extending from the outer level of the vascular bundles to the epidermis were also present.

Further development up to 1 day after flowering showed the layer of cells under the epidermis to be cork initials in which periclinal division had occurred as seen in Figure 2a, a cross section through the central part of the ovary wall. At this stage the first appearance of pigment was also observed in the upper part of the ovary as shown in Figure 2b, a cross section through the upper portion of the same ovary as illustrated in Figure 2a. Its appearance is also shown in tangential view in Figure 3. This was the first appearance of the innermost coloured layer which in gross morphological studies shows about 6 days after flowering. The most striking feature of this pigmented material was its intercellular rather than intracellular nature. It appeared in small patches between the cork layer and adjoining inner tissue but conformed to no cellular shape or pattern. Subsequently, these patches increased in size and coalesced to form an amorphous black band with points jutting into the cork layer. These points were probably formed by the material filling in the cavities between the cork cells. This condition is shown in Figures 4 and 5 which are a cross and a radial section of fruits 17 and 25 days after flowering, respectively. Radial sections made at these stages also showed the pigment was present between the cells of the ray-like structures.

In addition, Figures 4 and 5 show the pigment of the epidermis. Figures 6 and 7 complete the account. The former shows a cross section through the juncture of a black and a white stripe in a mature seed possessing a striped pattern only, while the latter is a section of a mature seed showing the pigment in all three regions. The preparation in Figure 7 was not stained.

It was apparent that the pigment of the striped pattern was carried in the epidermis and is intracellular in nature. It was also seen from section illustrated in Figure 6 that the structure of the pigmented and non-

pigmented epidermal areas of the striped seed was similar. The cork layer of the fruit illustrated in Figure 6 was thinner than in the other figures in which the inner layer of pigment was present. However, sections of other striped seeds without the inner layer of pigment showed that the cork layer may be as thick as that in Figures 4, 5 and 7. Examination of white seeds showed similar cell structures with the entire absence of the inner pigment band or any non-pigmented structure in that location.

In addition to showing the pigment of the epidermis and the inner pigment band, the section of Figure 7 also showed the heavy pigment in the cork layer itself. While it could not be seen in this section, since the pigment of the cork layer was purple, it was likely anthocyanin in nature and thus would be intracellular. This possibility may be checked by plasmolysis studies in living tissue.

The sections of the last four figures also showed that the parenchyma below the cork layer became sclerenchymatous, thus formed the rigid part of the seed. The characteristic thick-walled cells were seen in cross sections, while the view of Figure 5 showed the pits found in the cell walls of such tissue.

Investigations were not conducted to determine the chemical nature of the pigments. As stated above, it was felt the purple pigment of the cork layer was an anthocyanin. The inner layer, judging by its amorphous nature and the manner in which it filled in between the cells, was a resinous substance. No suggestion concerning the nature of the striped pigment can be made from the studies reported here.

DISCUSSION

Putt (5) has reported that the presence of pigment in the inner layer is dominant to its absence and dependent on a single genetic factor difference. Platchek (4) in earlier work with the "armour layer"; which, judging by his reports as well as those of Arnoldova (1) is synonymous with the inner layer discussed here, had also found the difference dependent on a single factor pair with pigmentation dominant. From an economic standpoint this is a valuable observation since Platchek credits the "armour layer" with resistance to larvae of the moth *Homoeosoma nebulella*. Bird and Allen (2) report economic damage to seed crops of sunflowers caused by the larvae of *H. electellum* in Manitoba in 1936. The writer has also observed the same insect damaging heads of a seed crop in Saskatchewan in several seasons, affecting as high as 15% of the plants in 1937. While not the same species name as the insect observed by Platchek, the one in Western Canada is no doubt closely related and may be synonymous. Though Platchek through his term "armour layer" implies a mechanical resistance, the writer in the present study has found the thick layer of sclerenchyma to be similar in both types of fruits. The resistance appears rather to be contributed by the inner pigment itself and thus to be physiologic in nature through repulsion of or toxicity to the insect larvae.

With the recent expansion of acreage of sunflowers being produced for seed in Western Canada the population of this insect, *Homoeosoma electellum*, will likely increase. Consequently, the incorporation of the inner

pigment layer with its associated insect resistance into new varieties appears to be a highly desirable objective of the breeding program. Because of the simplicity of its inheritance this objective could be easily attained.

The economic aspects of the other pigments observed are not yet known. Nor is much known concerning their inheritance. Preliminary observations indicate that the purple condition and the absence of striping are dominant to their respective contrasting characters. Segregating generations indicate complex inheritance.

SUMMARY

1. Histological studies of the wall of sunflower ovaries and fruits at stages ranging from before flowering up to maturity are reported.

2. The striped layer of pigment is contained in the epidermis of the ovary wall and is intracellular.

3. Purple pigment, believed intracellular, is found in the cork layer immediately below the epidermis of the ovary wall.

4. The inner pigment layer consists of an amorphous darkly pigmented substance which fills the intercellular spaces between the cork layer and the adjoining sclerenchyma tissue. It may be a resinous material.

5. No structural difference was observed between fruits with and without various pigments.

6. The amorphous layer appears to be synonymous with the "armour layer" of Platchek. Since he credits it with resistance to larvae of the moth *Homoeosoma nebullela* the incorporation of this layer into new varieties of sunflowers for seed production seems desirable.

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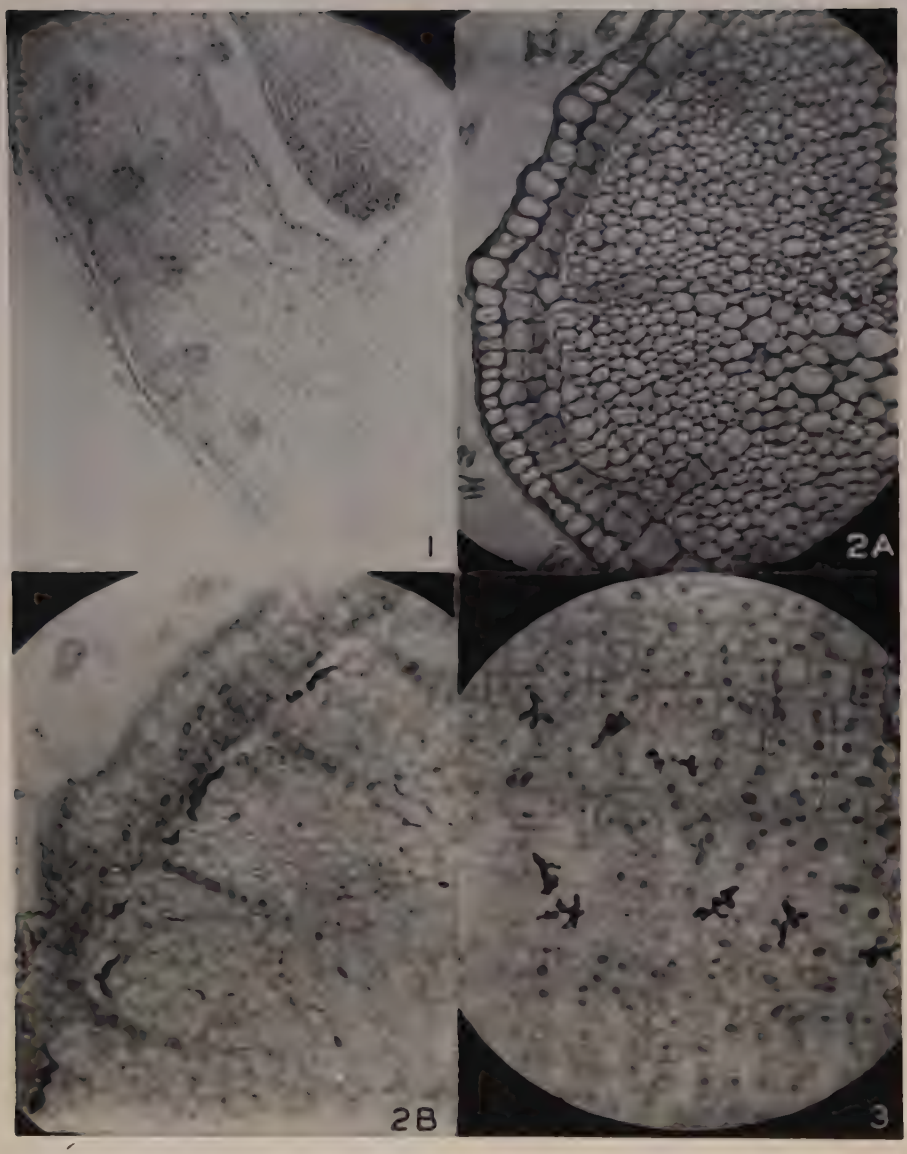

FIGURE 1. Cross section of ovary wall 4 days before flowering showing epidermis, single layer of cells below it, vascular bundles and numerous ray-like structures extending from vascular bundles to epidermis.

FIGURE 2. Cross section 1 day after flowering.
(a) In the central part of the ovary showing periclinal divisions in the layer of cells below the epidermis.
(b) In the upper part of same ovary showing first appearance of the inner amorphous pigment layer.

FIGURE 3. Tangential section 1 day after flowering showing early appearance of the inner amorphous pigment layer.

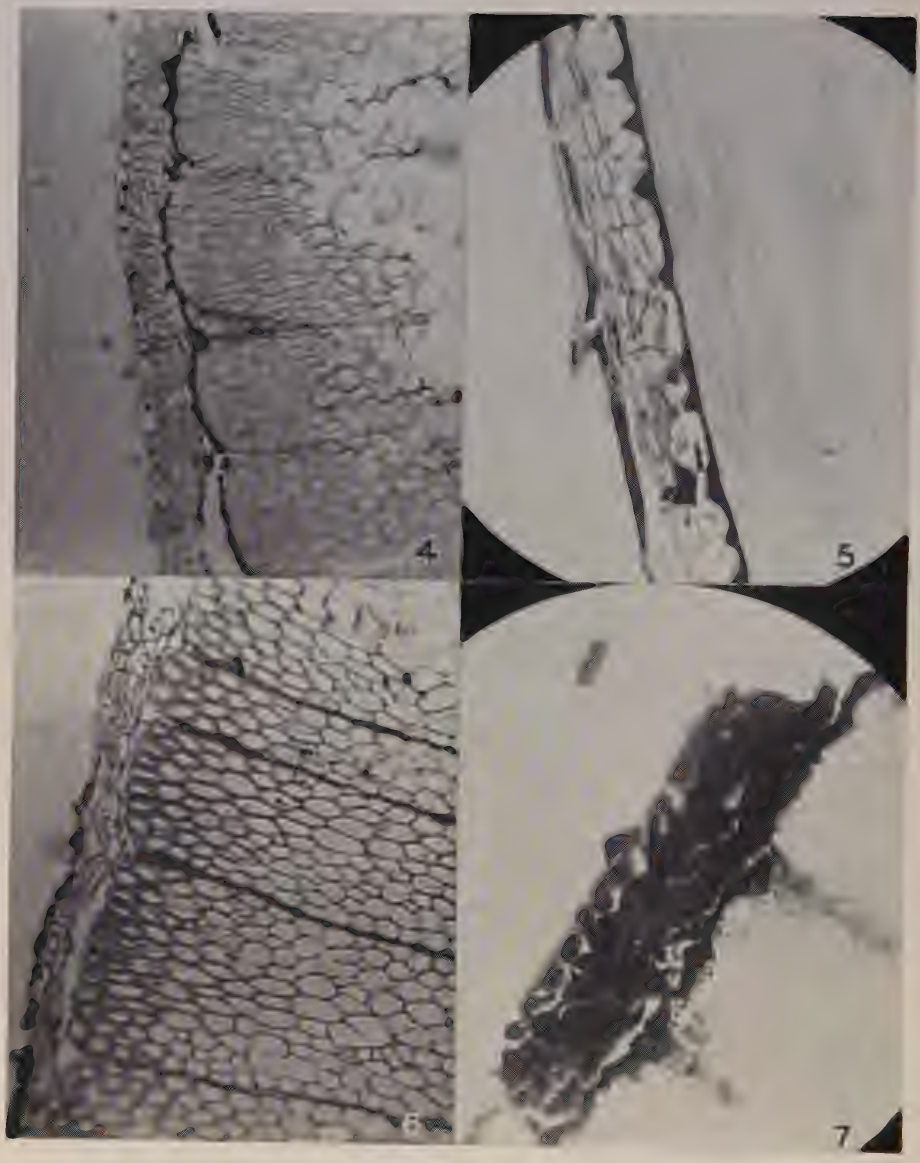

FIGURE 4. Cross section 17 days after flowering showing tendency of inner amorphous pigment layer to fill intercellular spaces and also the early appearance and intracellular location of the epidermal pigment.

FIGURE 5. Radial section 25 days after flowering showing inner amorphous pigment layer filling intercellular spaces of cork layer, intracellular nature of epidermal pigment and pits characteristic of sclerenchymatous tissue.

FIGURE 6. Cross section through junction of black and white stripe of mature fruit possessing epidermal pigment only. Note similarity of structure compared with fruits possessing other pigment.

FIGURE 7. Unstained cross section of fruit possessing epidermal pigment, purple pigment in cork layer and also the inner amorphous pigment layer.

SOME FACTORS AFFECTING APPLE YIELDS IN THE OKANAGAN VALLEY

I. TREE SIZE, TREE VIGOUR, BIENNIAL BEARING, AND DISTANCE OF PLANTING[1]

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The major apple producing section of British Columbia is in the Okanagan Valley and adjacent areas, in the southern interior of the province. For a number of reasons—some known, some unknown—the yield of apples in the Okanagan has not been as high on the average as has seemed desirable. For example, data compiled by the British Columbia Department of Agriculture (3) are summarized in Table 1. It will be seen that over a 4-year period, the average production per acre was only

TABLE 1.—APPLE ACREAGE AND PRODUCTION IN THE OKANAGAN VALLEY, 1937 TO 1940*

Variety	Acreage†	Average annual yield	Yield per acre‡
	acres	boxes	boxes
McIntosh	4,788	1,739,000	456
Delicious	3,418	628,000	270
Jonathan	2,122	616,000	342
Newtown	1,626	366,000	318
Winesap	1,380	224,000	330
Wealthy	981	271,000	288
Rome Beauty	904	246,000	312
Stayman	452	88,000	354
Duchess	209	57,000	300
Others	2,317	974,000	306
Total	18,197	5,209,000	378

* Compiled from data supplied by the British Columbia Department of Agriculture.
† Acreage in 1940, including both bearing trees and young trees.
‡ Based on assumption that production is almost entirely from trees 10 or more years old.

378 packed bushel boxes. The McIntosh variety contributed the most, both in total acreage and in yield per acre. Even the average McIntosh yield of 456 boxes per acre, however, cannot be considered impressive. As noted later in this report, this variety can and does produce—under favourable circumstances—up to 1000 packed boxes per acre per year.

Both research and observation indicate that a large number of factors have been instrumental in limiting apple yields in the Okanagan Valley. Some of these factors may be classed as directly nutritional in nature, others as only indirectly nutritional or as non-nutritional. Among the latter two classes may be mentioned codling moth, apple scab, crown rot, and winter injury, which are the subjects of research by representatives of both the Dominion and Provincial Departments of Agriculture. The

[1] Contribution No. 636 from the Division of Horticulture, Dominion Experimental Farms Service, Canada. This paper is a condensation of part of a thesis presented to the State College of Washington in partial fulfilment of the requirements for a Ph.D. degree in Horticulture.
[2] Assistant Superintendent in charge of nutritional investigations with tree fruits.

nutritional phase of the problem has also received much attention, partly through field tests of fertilizers, partly through minor element studies, and partly through soil and tissue analyses. In studies of the major elements conducted by the author, both the field application and analysis methods have been used.

In 1937, an investigation was started to determine the relationships between certain selected factors and apple tree performance. The primary factors selected for study were size of tree, distance of planting, vigour of tree, biennial bearing, N-P-K-Ca-Mg status of the tree, P-K-Ca-Mg status of the soil, soil texture, soil depth, soil pH, soil organic matter, moisture holding capacity of the soil, and root distribution. It was desired to determine the effects of these factors on mature, bearing trees growing under typical orchard conditions. The type of investigation decided upon, therefore, was a survey of selected groups of trees growing under a wide variety of conditions, the recording of the required data from these trees and from the soil, and the examination of these data by suitable statistical procedures. Most phases of this investigation have now been completed, and it is proposed to report the findings in a series of papers. This present paper covers the relationships found among tree size, tree vigour, biennial bearing, distance of planting, and tree yield.

REVIEW OF LITERATURE

No attempt will be made at this time to review in detail the relationships between nutritional factors and apple tree performance. It will be considered sufficient to note some of the major findings by other workers with respect to the three primary factors discussed in this paper; that is, size of tree, vigour of tree, and biennial bearing.

Size of Tree

A review of the literature on this factor will be found in a previous paper by the author (20). In that paper, it was reported that as McIntosh trees increased in size, the yield tended to increase. This increase was in direct proportion to the geometric mean of the circumference and the cross-sectional area of the trunk. It was found that in computing the per-acre yields, it was advantageous to relate the size of tree to the area of ground occupied per tree. In 1941, Overholser, Overley and Wilcox (12) reported highly significant positive correlations with Jonathan and Rome trees between both trunk circumference and trunk area on the one hand and yield of apples on the other hand.

Tree Vigour

Work done prior to 1937 on the relationship between tree growth and tree yield has been reviewed previously by the author (18). In 1937, Overholser, Overley and Barnhill (11) reported positive correlations between terminal length and increase in trunk circumference on the one hand and yield of apple trees on the other hand. In 1941, Overholser, Overley and Wilcox (12) reported highly significant positive correlations between terminal length and yield with Jonathan, but not with Rome or Winesap; and between increase in trunk circumference and yield with Jonathan and Winesap but not with Rome.

Biennial Bearing

It has occasionally been reported by investigators (14) that trees bearing biennially do not bear as heavily over a period of years as do trees bearing annually. The data supporting this contention, however, appear to be somewhat meagre.

Biennial bearing has been found by a number of workers to be influenced by the vigour of the trees. Roberts (13) reported in 1920 that high vigour was needed to maintain annual bearing. For annual bearing of the McIntosh, at least 12 to 16 inches of terminal growth were required. Since then he has reported similar findings (14). Bradford (2) found annual bearing to be induced by spring applications of nitrogenous fertilizers. Hooker (10) obtained similar results with fall applications. Harley and his co-workers have reported at different times (7, 8) that a high degree of vigour is necessary if other methods of inducing annual bearing are to be effective. A high degree of vigour by itself, however, was not found sufficient to induce annual bearing. This last has also been reported by Dorsey (5), Auchter and Schrader (1), Dickson (4) and Wallace and Spinks (16), who have increased tree vigour by pruning and by fertilizing with nitrogen, but have had little success from these treatments alone in overcoming biennial bearing.

Biennial bearing has been shown by a number of workers to cause differential effects on tree growth in two successive years. The literature on this prior to 1937 was covered by the author in a previous paper (18). In that paper, it was reported that the increase in trunk circumference was greater in the off year, but that the reverse was true of the terminal length. Similar findings were reported by Overholser, Overley and Wilcox (12) in 1941.

PROCEDURE

Selection of Trees

Only one variety of apple, the McIntosh, was used in this investigation. In 1937, some 400 bearing McIntosh trees were selected in grower-owned orchards. A deliberate attempt was made to include all the major soil series found in the irrigated part of the Okanagan Valley, as well as a wide variety of cultural treatments. The purpose in doing this was to include trees differing widely in bearing ability and in the factors being studied. Five McIntosh trees were selected in each plot of three fertilizer experiments in grower-owned orchards[3]; and in each of a number of other orchards, one or two groups of trees were chosen, usually with 5 trees to a group. Some groups were in straight rows, some in solid blocks. For want of a better term, these groups were called "plots." Except in the three special fertilizer experiments, all orchard operations (including fertilizing) were conducted by the growers in accordance with their own orchard routine.

Considerable care was exercised in selecting the trees. It was required that they be bearing, and mature or nearly so (Figure 1); that they appear healthy; and that they be well cared for by the growers, except in so far as fertilizing was concerned. Failure to fertilize, or to do so in what

[3] Two of these experiments were conducted by Mr. B. Hoy, of the British Columbia Department of Agriculture, and one was conducted by the author.

appeared inadequate amounts, was considered desirable in a certain proportion of the plots. Actually, a wide variation in the kind and amount of fertilizer used was included. The distance apart of the trees varied from 25 × 25 feet on the hexagonal to 35 × 35 feet on the square. In spite of the care in selection, it was found necessary in 1938 and 1939 to eliminate a number of plots. One reason was that the tree yields were found not to be suitable for comparison purposes unless each tree was surrounded on all sides by other trees of similar size and condition (20), and a number of the plots had been poorly selected in this respect. In addition, a few

TABLE 2.—PLOT AND TREE DISTRIBUTION

	Plot letter	No. of growers	No. of plots	No. of trees
Penticton	P	4	9	35
Summerland	S	2	2	10
Trepanier	T	3	6	23
East Kelowna	K	10	23	95
Belgo	B	6	10	46
Glenmore	G	4	7	32
Winfield	W	4	7	29
Oyama	O	4	4	20
Total		37	68	290

growers were unable to assist in recording the yields. These plots were partially replaced by others, selected in 1938 and 1939. The numbers of plots and trees finally used in each district are summarized in Table 2, and the 290 trees selected for statistical analysis are listed individually in Table 9 in the Appendix.

Tree Records

From 1937 to 1942, records were taken annually on trunk circumference, terminal length, total yield, and "profitable" yield (from 1939 only). In addition, observational notes were taken on disease and insect injury, fertilizer treatment, cover crop treatment, methods of irrigation, degree of thinning, type and severity of pruning, and any other factor that it was felt might have a bearing on the results.

The methods used in recording the trunk circumference and terminal length have already been described (17, 18). Both were measured in centimetres, to the nearest 0.1 centimetre. The terminal length procedure was shortened somewhat by selecting only 10 typical terminals per tree, and by measuring them consecutively along a steel tape and recording the total only. From the trunk circumference were calculated the cross-sectional area of the trunk, and the geometric mean between this and the trunk circumference. This last was found previously by the author (20) to be the best index of size of tree with the McIntosh, and was the one used in reaching the final conclusions in this investigation. To obtain a measure of tree size per unit of ground area occupied, the "geometric mean" was divided by the area of ground occupied per tree, in square feet (20). This measure was called the "trunk-ground ratio."

Terminal shoots were collected just prior to harvest in 1939 and 1940, for chemical analysis. The tip 5-cm. portions of 20 twigs per tree were selected each year, from the same type of terminal as was used for measuring terminal lengths. These twigs were dried and weighed, and the weights used as an indication of twig diameter. The chemical analyses will be reported in a subsequent paper.

FIGURE 1. Plot K54. In this plot, the trees were starting to meet in the centres. This was typical of a high percentage of the McIntosh plots.

To obtain the yield per tree, a tag was tacked to each tree prior to picking, and the grower marked down the number of loose bushel boxes picked, to the nearest half box. The accuracy of these records was checked by careful preharvest estimates. In a few cases, they were found to be unreliable and so were not used. The total yield per tree was obtained by adding together the boxes recorded at each picking plus the fruit on the ground. It was multiplied by the trees per acre to obtain the yield per acre.

In addition to total yield, "profitable" yield was recorded. This was considered to be fruit that showed 20% or more of solid red colour and that fell within the diameter range of $2\frac{1}{4}$ to $3\frac{1}{8}$ inches. Insect, disease, and mechanical injuries were ignored in making this classification. Just prior to harvest, careful estimates were made by three experienced workers of the "non-profitable" fruit on each tree. These estimates were checked by grading the fruit from a number of the trees. Deducting the non-profitable yields from the total yields gave the profitable yields.

The total yield per tree was used in determining the degree of biennial bearing. From the yields of each two consecutive years was calculated their "biennial bearing index," as follows:

$$\text{Biennial bearing index} = \frac{100\ (\text{difference between two yields})}{\text{sum of two yields}}.$$

Complete annual bearing gave an index of zero, and complete biennial bearing an index of 100. When the yield of the second year was the heavier, the index bore a plus sign; and when the yield of the first year

was the heavier, it bore a minus sign. In computing averages over a period of years, these signs were ignored. The biennial bearing index is a modification of the "I value" used by Hoblyn, Grubb, Painter and Wates (9). Biennial indices were also calculated for increase in trunk circumference, for terminal length, and for twig weight.

Statistical Analysis

Wherever the data were available, averages were calculated for each two successive years (i.e. for 1937 and 1938, for 1938 and 1939, etc.), and for each four successive years (i.e. 1937 to 1940, 1938 to 1941, and 1939 to 1942). In addition, averages were determined for five-year periods in certain cases, where the biennial bearing status changed during the course of the investigation. This will be discussed more fully under "Results." Primarily because of changes in the biennial bearing status, some periods were considered to provide more reliable averages than others. For a final summary of the data, the most reliable four- and five-year averages were used. These are presented in Table 9 in the Appendix, and the periods used in calculating the averages are indicated.

The principal methods used in analysing the data were correlation, regression, analysis of covariance, and scatter diagram studies (6, 15). In order to obtain data for further scatter diagram studies, the individual yields were adjusted, in order, for differences in size of tree, in tree vigour and in biennial bearing, by the covariance method. The data used to represent these three factors were trunk-ground ratio, terminal length, and biennial bearing index, respectively. The same studies were then made on these adjusted yields as were made on the unadjusted yields.

A scatter diagram was prepared for each pair of data correlated. By this means, it was possible to observe any wide deviations from the general trends. In each scatter diagram involving yield, also, an examination of the points was made in an attempt to determine approximately the "line of maximum yields." In most charts involving yield, the highest yields show some degree of continuity across the chart, such that a line could be drawn through the general area of these highest points. This line, therefore, represented approximately the highest yields actually obtained at each value of the factor concerned. It has proved useful in several ways; for example, setting standards of production toward which apple growers in the Okanagan should aim, and in indicating approximately the optimum values of the factor concerned.

RESULTS

So many records have been obtained during the six-year period that it would not be feasible to report all of them. It will be considered sufficient to present the most pertinent parts of the "summary" data, which will be found in Table 9 in the Appendix. For the most part, the findings obtained from analysing the summary data are of the same nature as those obtained from the two-year averages and from the other four-year averages. In order to shorten the presentation, accordingly, the findings from the summary data are the ones stressed in this paper. Where there has been any deviation from the "summary" results, this will be noted.

Changes in Biennial Bearing Status

Most of the 290 trees selected for study showed consistency in their yield progression. Some were completely biennial bearers and some almost completely annual bearers, with all stages between represented. In view of the fact that the profitable yields were not recorded until 1939, the summary data for the trees showing no breaks in progression were obtained by averaging the records for the four years 1939-42.

Quite a number of the trees did show breaks in their yield progression. These breaks commenced in some plots with exceptionally heavy yields in 1940, due to causes unknown, and in some plots with very light yields in 1941, due apparently to frost injury and tarnished plant bug. The effects of the 1940 conditions may be illustrated with four trees, whose yields (in boxes per tree) from 1937 to 1942 were as follows:

	1937	1938	1939	1940	1941	1942
B34E:	5	46	0	47	2	36
K25A:	44	0	59	37	30	37
K7B:	19	6	27	29	0	22
K7D:	20	24	28	41	0	24

With tree B34E, the yield progression was not affected. With tree K25A, biennial bearing was changed into almost-annual bearing. With tree K7B, the year of heavy bearing was changed. And with tree K7D, almost annual bearing was changed into definitely biennial bearing. The years selected for the summary data were 1939-42 with tree B34E, 1938-42 with trees K25A and K7D, and 1938-41 with tree K7B. The exceptionally light crop in some plots in 1941 had just the opposite effects on the yield progression.

Some Effects of Biennial Bearing

The effects of off-and-on-year bearing on the growth of the trees were determined by means of correlations between each pair of biennial indices. The results for 1939-40 are summarized in Table 3. An examination of the records for each two successive years reveals that the relationships indicated in this table were not confined to the 1939-40 data, but were general. Certain conclusions appear to be justified, as follows:

TABLE 3.—CORRELATIONS BETWEEN 1939-40 BIENNIAL INDICES

Two sets of data correlated		Coefficient of correlation
Biennial bearing index	Biennial trunk index*	−.729 (HS)†
Biennial bearing index	Biennial terminal index	+.634 (HS)
Biennial bearing index	Biennial twig weight index*	−.625 (HS)
Biennial trunk index	Biennial terminal index	−.536 (HS)
Biennial trunk index	Biennial twig weight index	+.520 (HS)
Biennial terminal index	Biennial twig weight index	−.561 (HS)

* "Biennial trunk index" is short for "biennial increase in trunk circumference index." "Twig weight" refers to the weight of the tip 5 cm. of the terminal shoots.

† HS stands for highly significant, with odds greater than 99 : 1.

1. In the on year, the increase in trunk circumference was considerably less than in the off year. This was definitely the closest relationship of those reported in Table 3.

2. In the on year, the terminals tended to be longer than in the off year. As noted in a previous paper by the author (18), this is no doubt a secondary relationship; that is, the length of terminal is dependent in large measure on the amount of food stored the previous season, which in turn is directly dependent on the size of crop that same year.

3. In the on year, the twigs tended to be lighter than in the off year. This may be explained by the fact that in the on year the annual thickness in new growth is less all over the tree (18). As confirmation of this, there was a high positive correlation between the year of heavy twigs and the year of large increase in trunk circumference.

4. As would be expected from the above relationships, there were strong tendencies for both the increase in trunk circumference and the twig weight per unit length to be high the same year that the terminals were short.

These findings corroborate those reported previously by the author (17, 18). It is apparent that when the general relationship between any one factor and yield is being studied, a single year's records are not as reliable as are two-year or four-year averages.

The standard deviations of the 1939-40 data used in the above correlations were as follows:

Biennial bearing index	52.5
Biennial trunk increase index	24.3
Biennial terminal index	18.2
Biennial twig weight index	8.2

Each index has a mean of approximately zero. The higher the standard deviation, therefore, the greater were the relative differences between the 1939 records and the 1940 records; that is, the greater was the "biennial" tendency.

Summary Data

The minima, maxima, means, and coefficients of variability of the principal summary data are shown in Table 4. It will be noted that there was a wide range of values represented by each type of measurement.

TABLE 4.—RANGE AND VARIABILITY OF SUMMARY DATA

Measurement	Minimum	Maximum	Mean	Coefficient of variability*
"Total" yield, in loose boxes per acre	503	1982	1098	26.6
"Profitable" yield, in loose boxes per acre	436	1592	941	25.6
Trunk-ground ratio	0.20	0.61	0.34	20.3
Increase in trunk circumference, in cm.	1.21	5.60	2.69	29.3
Terminal length, in cm.	11.5	42.9	25.5	20.0
Biennial bearing index	2	100	51	48.6

* The coefficient of variability is obtained by dividing the standard deviation by the mean, and multiplying by 100.

This was especially true of the biennial bearing index, which showed an exceptionally high coefficient of variability. A comparison with Table 1 indicates that the yields on these 290 trees averaged somewhat higher than the McIntosh mean for the Valley, even after taking into account the fact that it requires about 10 loose boxes to fill 7 packed boxes.

Summary Correlations

Some of the more important correlations that were obtained from the summary data are presented in Table 5. Only those partial correlations are shown that it was considered might add to the general information. For the most part, the coefficients indicated are similar to those obtained in each of the two-year periods from 1937 to 1942. Some exceptions to this general agreement, however, will be noted. Among the more important relationships revealed by the correlations are the following:

TABLE 5.—SOME CORRELATIONS OBTAINED FROM THE "SUMMARY" DATA

Two sets of data correlated		Factors eliminated	Coefficient of correlation
Trunk-ground ratio	Terminal length	None	+.042 (NS)*
Trunk-ground ratio	Biennial bearing index	None	+.049 (NS)
Terminal length	Biennial bearing index	None	−.064 (NS)
Total yield	Trunk-ground ratio	None	+.427 (HS)
Total yield	Terminal length	None	+.252 (HS)
Total yield	Terminal length	Trunk-ground ratio	+.260 (HS)
Total yield	Biennial bearing index	None	−.441 (HS)
Total yield	Biennial bearing index	Terminal length	−.442 (HS)
Total yield	Biennial bearing index	Trunk-ground ratio Terminal length	−.526 (HS)
Total yield	Trunk increase	Trunk-ground ratio	+.144 (S)
Profitable yield	Trunk-ground ratio	None	+.389 (HS)
Profitable yield	Terminal length	Trunk-ground ratio	+.087 (NS)
Profitable yield	Biennial bearing index	None	−.388 (HS)
Profitable yield	Biennial bearing index	Trunk-ground ratio	−.450 (HS)

* NS—Non-significant, with odds less than 19 : 1.
S—Significant, with odds between 19 : 1 and 99 : 1.
HS—Highly significant, with odds greater than 99 : 1.

1. Size of tree. An increase in size of tree (as measured by the trunk-ground ratio) was accompanied by no significant change in terminal length or in degree of biennial bearing. There does not appear to be any fundamental relationship represented by these correlations. As would be expected, however, the larger trees tended to bear heavier crops.

2. Terminal length. In view of the findings already noted by other investigators (2, 8, 10, 13, 14), the low correlation between terminal length and biennial bearing index is rather surprising. It should be noted that in 1937-38 this correlation was −0.320, and in 1940-41 it was −0.156, both "significant." Even assuming that there has been some effect of vigour on biennial bearing, the indications are that certain other factors have had a still greater effect. Observation indicates that these other factors are primarily meteorological in nature, in the area included in this investigation.

3. Increase in trunk circumference. The correlation between trunk increase and total yield was distinctly lower than that between terminal length and total yield, which contrasts with the higher correlation (already noted) between trunk increase and yield in any one year. This finding is interpreted as indicating that with the trees used in this investigation, those conditions in the tree associated with the terminal growth have, over a period of years, been more directly related to total yield than have those conditions associated with trunk growth. This points to terminal length being the more useful measure of tree vigour in routine work. As suggested previously by the author (19), however, both measurements are distinctly useful for this purpose.

4. Biennial bearing. It is sufficient to note that all correlations between biennial bearing and yield have been negative and "highly significant." In other words, there has been a marked tendency for the trees bearing biennially to have both lower total yields and lower profitable yields than those bearing annually.

Scatter Diagram Studies

Scatter diagrams were made of every pair of factors correlated. By this means, any abnormalities in the general trends were determined. Two different types of distribution are illustrated in Figures 2, 3 and 4. In the first type (Figures 2 and 4), the distribution shows a consistent trend in the one direction. The trend is positive in Figure 2, and negative in Figure 4. In the second type (Figure 3), the trend appears to change as the factor increases.

As already noted under "Procedure," maximum-yield lines were drawn in each scatter diagram involving yield. In most of the diagrams, these lines showed the same general trends as did the regression lines (Figure 2). An exception to this was where profitable yield was plotted against terminal length (Figure 3). The contrast between this and total yield plotted against terminal length was both marked and consistent, not only with the summary data but also with the two-year averages. As the terminal length increased, the maximum line of total yield increased steadily throughout almost the whole range (Figure 2), but the maximum line of profitable yield increased to a maximum at a terminal length of 25 to 30 cm. and then decreased again (Figure 3). When profitable yield was

plotted against terminal length within the highest frequency size groups of the other major factors, the results were practically the same. There is thus no evidence that the change in direction of the line of maximum yields was due to interaction between factors.

When a correlation is close to zero and the slope of the regression line is very low, it is usual for the distribution of points in the scatter diagram to assume an oval shape. In such a case, the line of maximum yields tends to rise to a maximum and to fall again. The question arises as to whether this might be the primary cause of the shape of the line of maximum yields

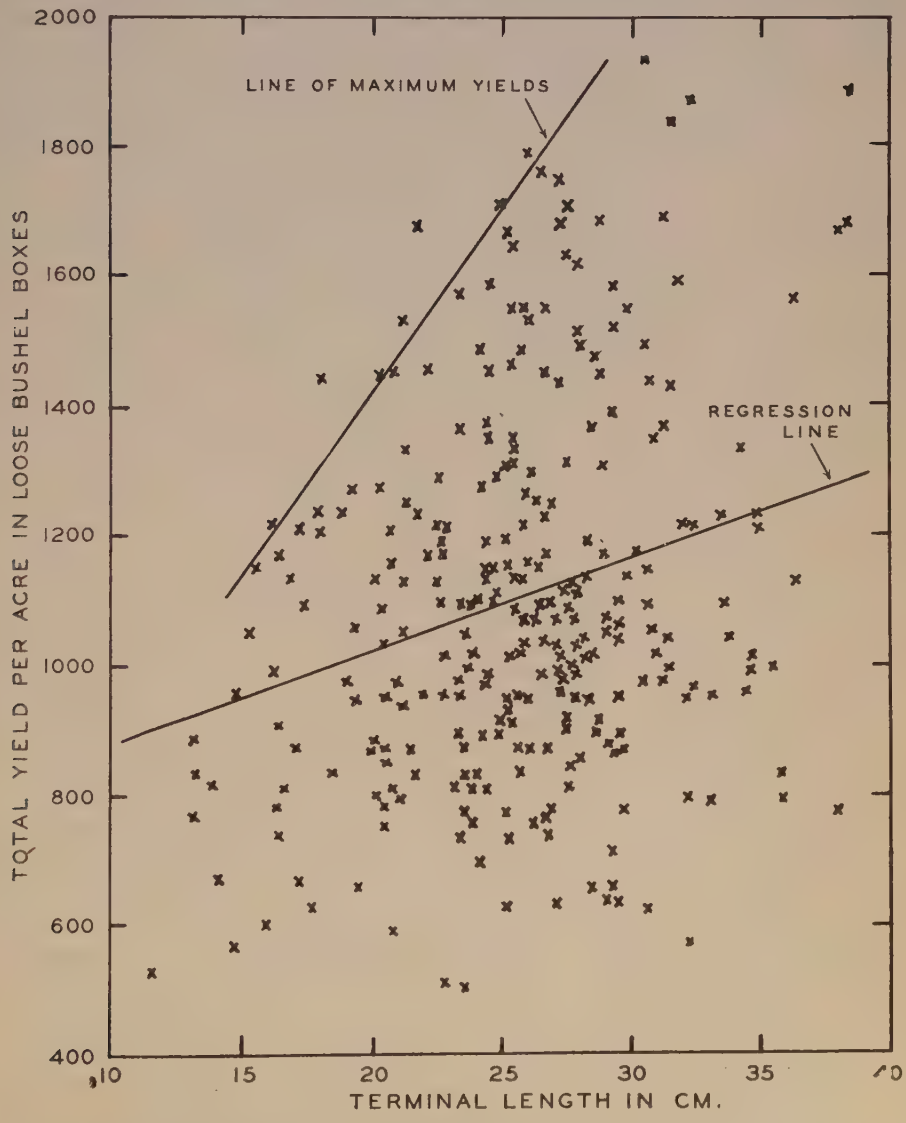

FIGURE 2. Scatter diagram of total yield per acre plotted against terminal length. The yields have been adjusted for differences in size of tree. $r = +0.260$ (Table 5).

in Figure 3. A comparison with a large number of other scatter diagrams representing low correlations indicates that it is not. It is not usual for the rise and fall to be as steep in relation to the ranges of the factor and function as they are in Figure 3.

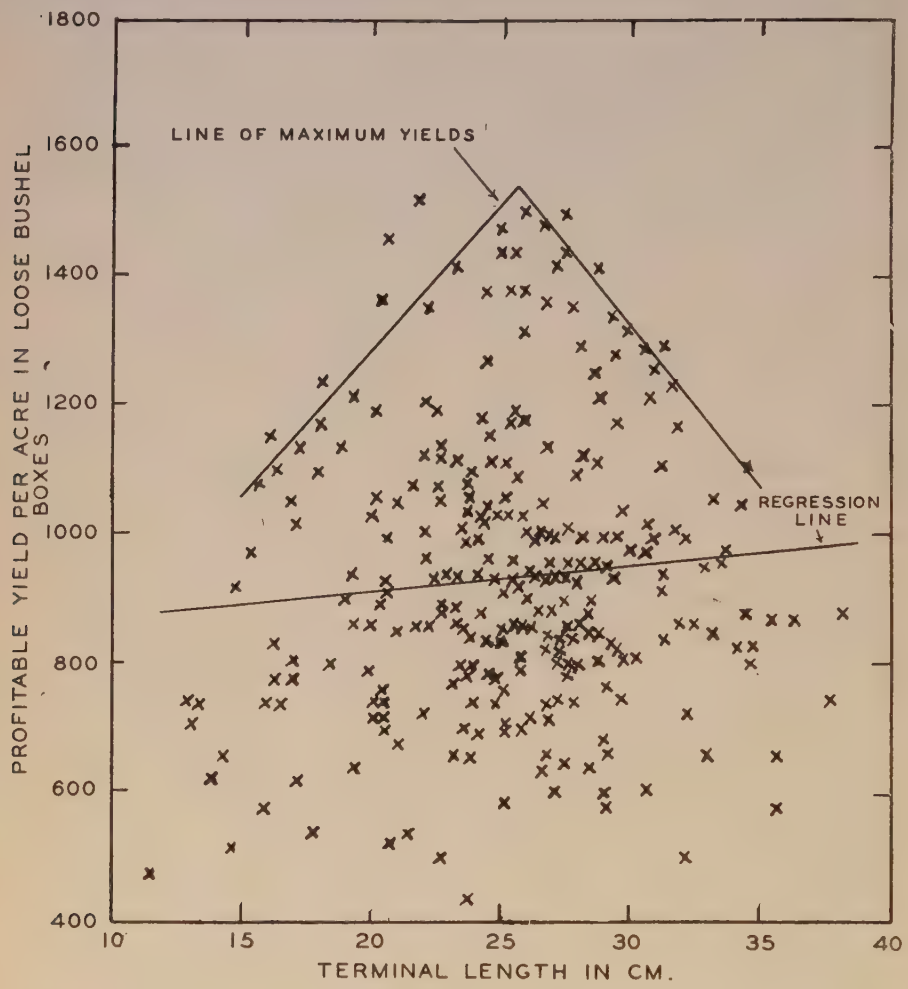

FIGURE 3. Scatter diagram of profitable yield per acre plotted against terminal length. The yields have been adjusted for differences in size of tree. $r = +0.087$ (Table 5).

The second degree polynomial regression line (6, 15) of the distribution in Figure 3 was found to be a curve with the equation

$$y = 1040 - 1.075\,x - .01865\,x^2,$$

in which y = profitable yield per acre,
and x = terminal length.

The maximum point on this curve comes at a terminal length of 28.8 cm. The sum of the squared deviations of yields, from this curvilinear regression line, is not significantly different from that of the rectilinear

regression line. However, the curvilinear line was considered to provide further evidence that the optimum terminal length lay somewhere between 25 cm. and 30 cm.

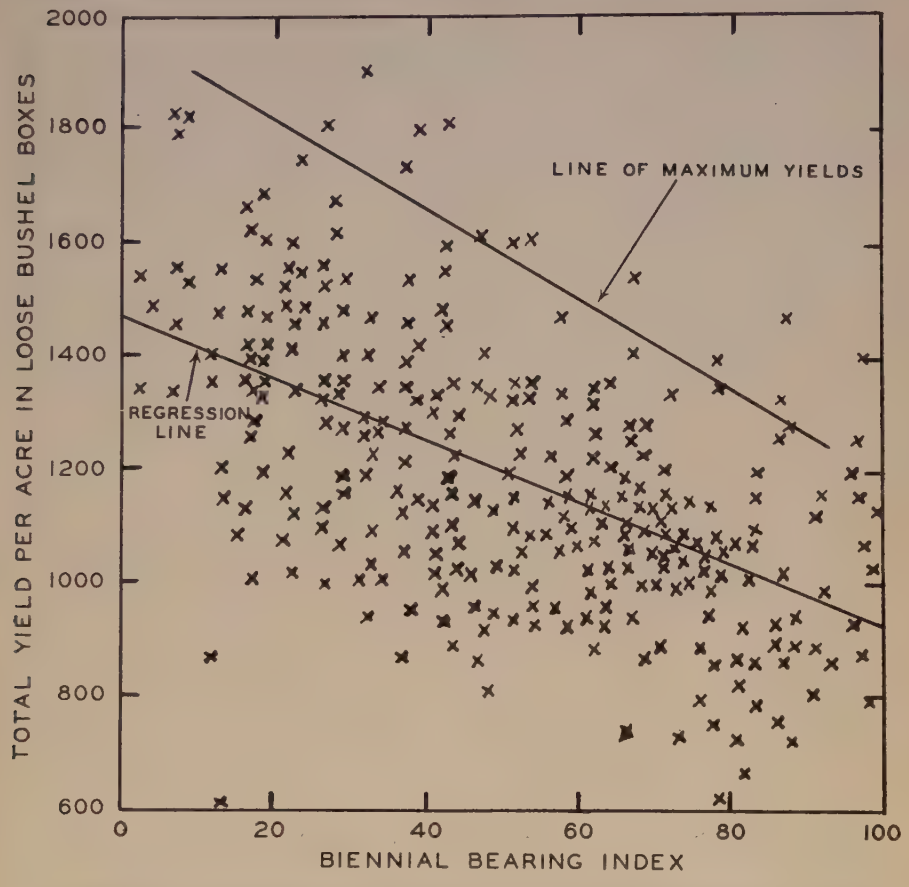

FIGURE 4. Scatter diagram of total yield per acre plotted against biennial bearing index. The yields have been adjusted for differences both in size of tree and in terminal length. $r = -0.526$ (Table 5).

The relationship between profitable yield and tree vigour (as represented by terminal length) can be explained largely by the effect of vigour on the percentage of "non-profitable" fruits. An examination of the field data has revealed that with increasing vigour there was at first little effect on the percentage of non-profitable fruits. When the terminals reached 25 to 30 cm. in length, however, there were sufficient oversized and poorly coloured fruits (both non-profitable) to offset the increase in total yield, and beyond that point increasing vigour was accompanied by an increase in non-profitable yield greater than the increase in total yield. The optimum terminal length appeared to depend to some extent on the degree of tree crowding: if the trees were thick in the centres and the limbs from neighbouring trees were crowding together, 25 cm. appeared to be better than 30 cm.; but if the trees were well opened up and well separated, the reverse appeared to hold true.

Regressions of Yield

The rectilinear regressions of yield on the three factors size of tree, tree vigour and biennial bearing were determined, these factors being represented by the trunk-ground ratio, terminal length, and biennial bearing index, respectively. The determinations were made in two ways: (1) from the slopes of the lines of regression of yield on the three factors; (2) from the slopes of the lines of maximum yield. The more pertinent results are summarized in Table 6. In each case, the slope of the line is expressed in terms of the amount of change in yield per unit change in the factor concerned. For example, the simple regression of total yield per acre on the trunk-ground ratio was + 1987; which means that for each change of 0.1 in the trunk-ground ratio, the average yield per acre changed by 199 boxes in the same direction. As will be seen from Table 6, the lines of maximum yield had greater slopes than the regression lines. This is no doubt due in part to the fact that the slope of the regression line is somewhat less than that of the general trend of the distribution. It will also be noted that the regressions are higher for total yield than for profitable yield.

TABLE 6.—COEFFICIENTS OF REGRESSION OF YIELD PER ACRE ON TRUNK-GROUND RATIO, TERMINAL LENGTH AND BIENNIAL BEARING INDEX

Type of line used	No. of factors eliminated	Regression of yield on		
		Trunk-ground ratio	Terminal length	Biennial bearing index
		boxes	boxes	boxes
A. *Total yield per acre*				
Regression line	none	+1987	+14.4	−516
Regression line	2*	+1764	+16.0	−535
Maximum yield line	none	+3300	+50.0	−933
B. *Profitable yield per acre*				
Regression line	none	+1354	—†	−387
Regression line	2*	+1269	—†	−397
Maximum yield line	none	+2583	35.0‡	−514

* When two factors were eliminated, this means that the regression coefficient represents the trend when the other two factors were held constant.
† Correlation too low to justify calculating the regression.
‡ + 35.0 below a terminal length of 27.5 cm., and − 35.0 above 27.5 cm.

The regression coefficients shown in Table 6 do not represent the average effects of the three factors on yield; nor can those for any one factor be compared directly with those for the other factors. In order to convert the data into figures that would have a more direct practical application, the change in yield per *average* deviation of each factor from the optimum was calculated. For this purpose, the optima were considered to be a trunk-ground ratio of 0.37 and up, a terminal length of 27.5 cm., and a biennial bearing index of zero. With trees 30 × 30 feet apart on the square, a trunk-ground ratio of 0.37 is represented by a trunk diameter of about 14 inches. The figures thus obtained for profitable yield are indicated in Table 7.

If it can be assumed that the relationships found between the three factors and yield represent actual effects, either direct or indirect, then the data of Table 7 may be considered to provide a suitable basis for comparing these effects. In the case of teminal length, the figures given will of course

TABLE 7.—AVERAGE LOSS OF PROFITABLE YIELD PER ACRE, ATTRIBUTABLE TO TRUNK-GROUND RATIO, TERMINAL LENGTH AND BIENNIAL BEARING INDEX

Line used as basis	No. of factors eliminated	Loss of yield attributable to		
		Trunk-ground ratio	Terminal length	Biennial bearing index
		boxes	boxes	boxes
Regression line	none	55	—	187
Regression line	2	52	—	192
Maximum yield line	none	105	110	248
Average deviation of factor from Optimum		0.0408	3.150	0.4825

refer not to any direct effect of terminal length itself on yield, but rather to the effect of all those conditions that are associated with terminal length; that is, what is commonly called tree vigour. It will be noted that the average losses attributable to biennial bearing have been much greater than those attributable to the other two factors.

Distance of Planting

The trees were divided into four groups, in accordance with their distance apart of planting, and a number of different procedures were tried for evaluating the yield differences between these groups. Only two of the groups contained sufficient trees for reliable comparison: (1) trees occupying 780 to 840 square feet of space; (2) trees occupying 900 square feet of space. By all methods of comparison, the yields were somewhat higher in the first of these two groups than in the second. Although the differences were not always "significant" (odds 19 : 1 or higher), they were quite consistent. The conclusion appeared justified, therefore, that under the conditions of this investigation the trees occupying 780 to 840 square feet of space tended to bear more fruit per acre than did those occupying 900 square feet. Some of the averages that were compared are shown in Table 8. It will be noted that successive adjustments increased the averages. This was caused by adjusting to the optimum value rather than to the mean of each factor.

TABLE 8.—AVERAGE YIELDS PER ACRE IN DISTANCE-OF-PLANTING GROUPS

	Area occupied per tree	
	780-840 sq. ft.	900 sq. ft.
No. of trees in group	95	186
A. *Total yield per acre*		
Unadjusted	1228	1050 (HS)*
Adjusted for trunk-ground ratio	1261	1179 (NS)
Adjusted for all three factors	1525	1435 (S)
B. *Profitable yield per acre*		
Unadjusted	1051	920 (S)
Adjusted for trunk-ground ratio	1091	1022 (NS)

* These letters indicate the significance of the difference between each pair of means:
NS—Non-significant, with odds less than 19 : 1.
S—Significant, with odds between 19 : 1 and 99 : 1.
HS—Highly significant, with odds greater than 99 : 1.

The higher yields obtained with the closer planting appear to be associated in part with a greater size of tree per unit area of ground occupied. The trunk-ground ratio was distinctly higher, on the average, with the "780-840" group; and observation indicated that the tops of the trees in this group occupied the orchard space more fully than they did in the "900" group. With the older trees, this difference was not so obvious. It appears that the more closely planted trees come into full production per acre the sooner, but that they also become too crowded for maximum production the sooner. The findings of this investigation, therefore, cannot be applied indiscriminately to other groups of trees either in the Okanagan Valley or elsewhere.

Locality

Comparisons between localities were made in the same manner as between distances of planting. No detailed report on the results obtained will be made at this time. It will be considered sufficient to record that no differences between districts were found that could not be attributed to differences in size of tree, vigour of tree, and biennial bearing. In other words, there was no evidence to indicate either an increase or a decrease in the potential yield per acre of the McIntosh trees as they were located progressively father north from Penticton to Oyama.

DISCUSSION

In the opinion of the author, the most important finding reported in this paper is the marked effect of biennial bearing on average tree yield. Because of this effect, and because of the prevalence of biennial bearing, the losses of yield from this cause constitute a serious problem in the Okanagan Valley. Another finding of value is that under the conditions of this investigation the optimum degree of vigour of McIntosh trees is indicated by about 25 to 30 cm. (10 to 12 inches) of average terminal growth. This of course does not necessarily apply to other varieties or to other districts. The discovery that even in mature orchards the more closely planted trees have borne the heaviest crops of profitable fruit per acre indicates that wide planting may not be essential to profitable apple production; however, further study is required before it can be concluded that the planting distance recommended for the Okanagan should be reduced below 30 × 30 feet on the square.

SUMMARY

In 1937, McIntosh trees were selected for study in groups of 5 or less, in grower-owned orchards from Penticton to Oyama in the Okanagan Valley. All trees were mature or nearly so, and most of them were surrounded by other trees of the same size and variety. Final statistical analyses were made on 290 selected trees.

For six years (1937-42), records were taken on trunk circumference, terminal length, total yield, and "profitable" yield; and twig weights were determined for two years (1939-40). The profitable yield consisted of fruits between the sizes of $2\frac{1}{4}$ and $3\frac{1}{8}$ inches, and with a solid red colour of at least 20%. From these records were calculated the annual increase in trunk circumference, the trunk-ground ratio (a measure of tree size per

unit of ground space occupied), and the biennial bearing index (a measure of the degree of biennial bearing). The tree yields were adjusted individually for differences in trunk-ground ratio, terminal length, and biennial bearing index. Studies were made primarily by means of correlation, regression, covariance, and scatter diagrams.

Biennial bearing was found to have a marked effect on tree growth. The year of high yield proved to be the year of small increase in trunk circumference, long terminal length, and small terminal diameter. The inter-annual differences were greatest with yield, and progressively less with trunk increase, terminal length, and twig diameter. As a result of these relationships, it was found necessary to use at least two-year averages in studying factorial effects on average yield.

The correlations among the two-or-more-year averages indicated the following trends: (1) The larger the tree, the greater were the total yield and the profitable yield per acre. (2) The longer the terminals, the greater was the total yield but not the profitable yield. (3) The greater the degree of biennial bearing, the less were the total yield and profitable yield. This last effect was the most marked of the three. Biennial bearing appeared to be more closely associated with meteorological conditions than with lack of tree vigour.

The factorial optima determined from the scatter diagrams were as follows: trunk diameter 14 inches or larger (with trees planted 30 × 30 feet apart on the square), terminal length 25 to 30 cm., and biennial bearing zero (i.e. 100% annual bearing). The average losses of yield resulting from deviations of the three major factors from their optima were much the greatest with biennial bearing.

The trees occupying less than 900 square feet per tree produced higher yields per acre, both of total and of profitable fruit, than did those occupying 900 or more square feet. No differences were found among districts that could not be attributed to differences in the three major factors studied.

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APPENDIX

TABLE 9.—"SUMMARY" DATA FROM McINTOSH TREES

1	2	3	4	5	6	7	8	9	10	11	12	13
Plot no.*	Tree no.	Years averaged	A†	B†	C†	D†	Total yield‡, adjusted for				Profitable yield‡, adjusted for	
							O†	A†	AC†	ACD†	O†	A†
				cm.	cm.		boxes	boxes	boxes	boxes	boxes	boxes
P2	2-1	1938–41	.23	1.44	23.2	55	975	1275	1300	1594	875	1106
	2-3	1938–41	.29	1.87	25.5	90	1124	1318	1311	1792	1095	1245
	2-4	1938–41	.37	2.55	25.8	90	1252	1305	1294	1775	1171	1212
	3-1	1938–41	.23	2.65	37.8	79	771	1071	894	1317	721	952
	3-3	1938–41	.27	2.05	28.2	38	938	1167	1123	1326	866	1043
P3	6-1	1938–41	.29	2.47	29.6	18	1082	1276	1212	1308	1032	1182
	6-4	1938–41	.32	2.35	29.2	66	634	775	717	1070	590	799
	7-1	1938–41	.30	2.22	26.5	21	985	1161	1140	1252	930	1066
	7-3	1938–41	.31	2.85	26.9	69	759	918	892	1261	725	847
	7-4	1938–41	.27	2.52	33.7	66	1037	1266	1146	1199	962	1139
P4	10-1	1938–41	.30	2.67	27.9	86	856	1032	992	1452	798	934
	10-3	1938–41	.32	2.22	25.6	66	833	974	966	1319	799	1008
	10-4	1938–41	.27	2.27	28.7	54	914	1143	1092	1381	839	1016
	11-1	1938–41	.30	2.30	28.7	70	895	1071	1020	1394	837	973
	11-3	1938–41	.30	2.65	29.4	71	863	1039	978	1358	820	956
P1	14-1	1938–41	.26	2.50	30.6	83	616	862	785	1229	592	782
	14-3	1938–41	.25	3.37	25.2	41	622	886	883	1103	572	776
	14-4	1939–41	.31	3.30	30.9	84	1056	1215	1133	1583	992	1114
P9	A	1939–42	.39	3.60	31.5	39	1830	1848	1758	1966	1518	1532
	B	1939–42	.35	3.45	26.5	41	1762	1850	1829	2049	1491	1559
	C	1939–42	.37	3.70	30.5	47	1933	1986	1910	2161	1592	1633
	D	1939–42	.34	3.62	25.4	26	1462	1568	1562	1700	1298	1379
P10	D	1939–42	.35	3.32	32.3	35	1862	1950	1849	2036	1463	1531
P5	A	1939–42	.46	3.17	42.9	33	1429	1323	1075	1252	913	832
	B	1939–42	.47	2.17	38.0	4	1667	1543	1363	1384	1081	986
	C	1939–42	.54	3.02	38.1	16	1680	1434	1253	1339	866	676
	D	1939–42	.55	3.17	38.4	22	1982	1718	1533	1615	1353	1149
	E	1939–42	.51	3.20	36.2	22	1562	1368	1213	1331	1221	1071
P7	B	1939–42	.46	2.30	23.4	42	1365	1259	1281	1505	1116	1035
	D	1939–42	.37	2.32	26.7	66	1036	1089	1065	1418	876	917
	E	1939–42	.38	2.75	27.8	61	986	1021	993	1319	829	856
P6	A	1939–42	.32	1.87	29.6	41	951	1092	1028	1248	786	995
	B	1939–42	.32	2.45	27.5	66	915	1056	1021	1374	786	995
	C	1939–42	.44	2.22	23.3	45	956	886	910	1151	850	796
	D	1939–42	.45	1.82	26.4	32	1084	996	977	1148	930	862
S12	A	1939–42	.32	1.37	20.7	98	587	728	787	1312	514	723
	B	1939–42	.37	2.15	20.3	90	781	834	899	1380	714	755
	C	1939–42	.36	1.77	17.6	94	623	693	795	1298	538	595
	D	1939–42	.33	1.87	23.3	95	732	856	880	1389	642	737
	E	1939–42	.31	1.67	14.7	91	574	733	876	1363	508	630

* Plots arranged in table according to their position in each district.

† A—Trunk-ground ratio. B—Increase in trunk circumference.
C—Terminal length. D—Biennial bearing index.
O—No adjustment.

‡ All yields are expressed in terms of loose bushel boxes per acre.

APPENDIX—Continued

TABLE 9.—"SUMMARY" DATA FROM McINTOSH TREES—*Continued*

1	2	3	4	5	6	7	8	9	10	11	12	13
Plot no.*	Tree no.	Years averaged	A†	B†	C†	D†	Total yield‡, adjusted for				Profitable yield‡, adjusted for	
							O†	A†	AC†	ACD†	O†	A†
				cm.	cm.		boxes	boxes	boxes	boxes	boxes	boxes
S10	A	1939–42	.33	2.70	27.1	71	628	752	723	1103	592	787
	B	1939–42	.38	2.70	24.2	77	698	733	744	1156	680	707
	C	1939–42	.38	2.70	22.8	76	514	549	579	985	488	515
	D	1939–42	.39	3.80	29.3	38	636	654	595	798	566	580
	E	1939–42	.50	3.50	27.6	47	1072	896	860	1111	1002	866
T2	A	1939–42	.40	2.45	21.1	100	793	793	847	1382	678	678
	B	1939–42	.47	2.92	31.8	100	1217	1093	999	1534	1001	906
	D	1939–42	.58	3.65	28.9	100	1441	1124	1070	1605	1208	963
	E	1939–42	.61	3.72	31.2	100	1367	997	911	1446	1108	822
T3	A	1939–42	.45	3.32	34.8	76	1238	1150	1014	1420	1077	1009
	B	1939–42	.50	3.62	30.8	85	1345	1169	1089	1544	1216	1080
	D	1939–42	.40	3.25	34.2	83	1335	1335	1208	1652	1140	1140
	E	1939–42	.55	3.47	29.9	97	1551	1287	1219	1738	1313	1109
T6	A	1939–42	.29	2.76	20.6	97	1158	1352	1413	1932	1021	1171
	B	1939–42	.35	3.72	28.9	90	1301	1389	1335	1816	1117	1185
	C	1939–42	.27	2.95	30.5	100	1144	1373	1297	1932	967	1144
	D	1939–42	.22	3.00	32.5	95	960	1277	1173	1682	844	1089
	E	1939–42	.23	2.99	33.2	98	953	1253	1139	1664	839	1068
T7	A	1939–42	.28	3.07	30.1	70	1169	1381	1310	1684	979	1142
	B	1939–42	.27	2.77	24.9	75	1107	1336	1337	1738	930	1107
	C	1939–42	.25	2.85	29.0	80	1169	1433	1378	1806	983	1187
	D	1939–42	.28	3.60	31.9	94	1019	1231	1136	1639	855	1018
	E	1939–42	.29	3.70	33.5	97	1099	1293	1175	1694	948	1098
T8	A	1939–42	.38	3.22	31.5	27	1421	1456	1366	1510	1230	1257
	B	1939–42	.41	2.50	30.5	40	1489	1471	1395	1609	1282	1268
	C	1939–42	.43	1.97	25.3	27	1316	1263	1259	1403	1108	1067
	D	1939–42	.44	1.60	27.5	7	1623	1553	1518	1555	1431	1377
T9	A	1939–42	.37	2.52	22.6	58	1211	1264	1297	1607	1124	1165
K1	B15	1938–41	.23	1.95	17.1	53	673	973	1082	1366	610	831
	D15	1938–41	.30	2.35	17.2	46	1083	1259	1367	1613	1016	1152
	H15	1938–41	.30	2.70	20.0	50	1310	1314	1382	1651	1020	1156
K2	S15	1939–42	.31	1.62	17.2	21	1211	1370	1478	1590	1339	1261
	S16	1940–41	.34	2.00	13.0	16	1381	1487	1653	1739	1248	1329
	U15	1938–42	.27	1.92	20.0	36	876	1105	1174	1366	850	1027
	U16	1938–42	.30	2.20	18.0	41	1238	1414	1511	1731	1179	1315
	V15	1938–42	.34	1.98	16.0	20	1216	1322	1446	1553	1141	1222
K6	Z10	1938–42	.25	3.18	23.7	31	1187	1451	1469	1635	1080	1284
	Z11	1938–42	.30	3.22	22.3	29	1254	1430	1467	1622	1120	1256
	AA10	1938–42	.22	2.96	22.2	13	1042	1359	1398	1467	955	1200
K21	DD2	1938–41	.24	2.27	20.3	15	871	1153	1218	1566	744	962
	EE2	1038–41	.30	3.42	21.7	59	956	1132	1178	1494	858	994
	GG2	1938–41	.37	3.62	16.8	64	1476	1190	1304	1642	1041	1218
	HH2	1938–41	.31	3.30	21.1	67	932	1091	1145	1503	841	963
	II2	1938–41	.35	3.72	25.9	70	1024	1112	1100	1474	850	918

* Plots arranged in table according to their position in each district.
† A—Trunk-ground ratio. B—Increase in trunk circumference.
C—Terminal length. D—Biennial bearing index.
O—No adjustment.
‡ All yields are expressed in terms of loose bushel boxes per acre.

APPENDIX—Continued

TABLE 9.—"SUMMARY" DATA FROM McINTOSH TREES—*Continued*

1	2	3	4	5	6	7	8	9	10	11	12	13
Plot no.*	Tree no.	Years averaged	A†	B†	C†	D†	Total yield‡, adjusted for				Profitable yield‡, adjusted for	
							O†	A†	AC†	ACD†	O†	A†
				cm.	cm.		boxes	boxes	boxes	boxes	boxes	boxes
K7	A	1938–41	.33	3.95	26.0	41	941	1065	1051	1271	851	946
	B	1938–41	.29	2.90	25.1	55	723	917	916	1210	686	836
	C	1939–42	.34	2.00	20.5	73	953	1059	1121	1511	919	1000
	D	1938–42	.34	3.12	30.6	72	1094	1200	1123	1508	1012	1093
	E	1938–41	.33	4.20	28.0	44	1037	1161	1119	1355	920	1015
K9	A	1939–42	.40	2.07	14.7	68	949	949	1092	1456	908	908
	B	1939–42	.29	1.52	20.8	72	802	996	1054	1439	733	883
	C	1939–42	.45	2.15	25.2	84	908	820	817	1267	845	777
	D	1939–42	.38	2.17	20.8	79	973	1008	1066	1489	914	941
	E	1939–42	.39	2.10	23.7	78	830	848	866	1283	782	796
K27	A	1939–42	.39	1.67	18.4	81	839	857	948	1382	796	810
	B	1939–42	.39	2.45	16.6	57	810	828	944	1249	761	775
	C	1939–42	.33	2.07	16.4	73	740	864	983	1373	726	821
	D	1939–42	.36	1.77	14.1	86	669	739	890	1350	642	696
	E	1939–42	.39	2.00	15.8	84	600	618	745	1195	579	593
K16	A	1939–42	.31	2.30	22.9	64	945	1104	1133	1475	878	1000
	B	1939–42	.37	2.22	23.5	69	1084	1137	1158	1527	1005	1046
	C	1939–42	.36	2.65	22.8	76	1017	1087	1117	1523	936	990
	D	1939–42	.37	2.72	24.2	64	1278	1331	1342	1684	1180	1221
	E	1939–42	.32	2.32	29.0	65	1073	1214	1159	1507	945	1154
K10	A	1938–41	.36	1.82	22.1	17	1455	1525	1565	1656	1350	1404
	B	1938–41	.30	1.97	23.6	54	762	938	957	1246	692	828
	C	1938–41	.32	2.20	23.5	31	1043	1184	1205	1371	929	1138
	D	1938–41	.39	3.80	22.7	47	949	967	999	1250	882	896
K54	A	1939–42	.34	1.47	24.2	16	1481	1587	1598	1684	1335	1416
	B	1939–42	.36	2.15	26.1	14	1298	1368	1353	1428	1118	1172
	C	1939–42	.33	2.62	27.2	23	1432	1556	1526	1649	824	919
	D	1939–42	.35	1.90	27.5	18	1312	1400	1365	1461	944	1012
	E	1939–42	.37	2.87	25.6	13	1138	1191	1183	1252	991	1032
K11	A	1939–42	.23	2.50	23.7	46	817	1117	1135	1381	690	921
	B	1939–42	.26	3.35	27.7	55	1113	1359	1322	1616	839	1029
	E	1939–42	.22	2.27	30.3	40	969	1286	1213	1427	799	1044
K12	A	1939–42	.33	2.22	29.3	43	1393	1517	1458	1688	1169	1264
	B	1939–42	.27	2.55	25.1	52	930	1159	1158	1436	757	934
	C	1939–42	.32	2.25	26.6	22	1223	1364	1342	1460	1048	1257
	D	1939–42	.27	1.77	20.5	41	1023	1252	1314	1534	884	1061
	E	1939–42	.26	2.10	25.7	56	1210	1456	1446	1746	1017	1207
K13	A	1939–42	.30	2.42	25.7	51	1066	1242	1232	1505	915	1051
	B	1939–42	.30	1.87	23.9	52	1169	1345	1360	1638	1030	1166
	C	1939–42	.32	2.55	28.2	57	1006	1147	1103	1408	860	1069
	D	1939–42	.33	1.90	26.8	55	1253	1377	1352	1646	1127	1222
	E	1939–42	.30	2.35	24.5	45	1343	1519	1526	1767	1150	1286

* Plots arranged in table according to their position in each district.

† A—Trunk-ground ratio. B—Increase in trunk circumference.
C—Terminal length. D—Biennial bearing index.
O—No adjustment.

‡ All yields are expressed in terms of loose bushel boxes per acre.

APPENDIX—Continued

TABLE 9.—"SUMMARY" DATA FROM McINTOSH TREES—*Continued*

1	2	3	4	5	6	7	8	9	10	11	12	13
Plot no.*	Tree no.	Years averaged	A†	B†	C†	D†	Total yield‡, adjusted for				Profitable yield‡, adjusted for	
							O†	A†	AC†	ACD†	O†	A†
				cm.	cm.		boxes	boxes	boxes	boxes	boxes	boxes
K14	A	1939–42	.28	2.40	24.4	54	1132	1344	1352	1641	1018	1181
	B	1939–42	.25	1.80	27.7	53	999	1263	1226	1510	842	1046
	C	1939–42	.31	1.92	19.0	67	975	1134	1217	1575	890	1012
	D	1939–42	.30	2.45	26.8	43	1090	1266	1241	1471	948	1084
	E	1939–42	.25	2.20	28.1	39	1139	1403	1360	1568	988	1192
K15	C	1939–42	.24	1.67	26.8	51	732	1014	989	1262	642	860
	D	1939–42	.28	1.22	23.8	45	751	963	980	1221	654	817
	E	1939–42	.25	1.37	23.6	46	503	767	786	1032	436	640
K46	B	1938–42	.22	2.58	29.2	48	659	967	918	1175	646	891
	C	1938–42	.27	2.46	27.3	35	988	1217	1185	1372	781	958
	E	1938–42	.29	3.76	27.9	59	1031	1225	1185	1501	785	935
K51	A	1939–42	.36	2.80	23.6	60	993	1063	1082	1403	848	902
	B	1939–42	.28	3.05	27.5	71	811	1023	988	1368	636	799
	E	1939–42	.33	3.07	29.1	52	1041	1165	1108	1386	885	980
K22	A	1939–42	.35	2.30	25.2	67	1110	1198	1195	1553	1021	1089
	B	1939–42	.30	2.47	24.7	67	1096	1272	1276	1634	1021	1157
	C	1939–42	.29	2.20	20.2	67	1269	1463	1529	1887	1185	1335
	D	1939–42	.25	2.30	21.6	67	1110	1374	1421	1779	1069	1273
	E	1939–42	.27	2.27	27.0	70	1069	1298	1270	1644	999	1176
K25	B	1938–42	.37	2.78	25.7	38	1480	1533	1523	1726	1309	1350
	C	1938–42	.34	2.60	30.7	37	1430	1536	1457	1655	1253	1334
K24	A	1939–42	.34	1.85	25.3	27	1307	1413	1409	1553	1165	1246
	B	1939–42	.42	2.37	25.9	87	1538	1503	1491	1956	1376	1349
	E	1939–42	.36	2.62	25.3	54	1543	1613	1609	1898	1433	1487
K49	B	1938–42	.29	4.18	34.8	32	1213	1407	1271	1442	818	968
	C	1938–42	.30	3.60	29.8	40	1139	1315	1249	1463	1115	1026
	D	1938–42	.23	3.04	26.7	34	1028	1328	1304	1486	815	1046
K8	A	1940–41	.34	3.40	18.0	30	1440	1546	1643	1803	1230	1311
	B	1940–41	.35	3.44	25.3	40	1350	1438	1434	1648	1103	1171
	C	1939–42	.32	2.97	27.5	39	1704	1845	1810	2018	1487	1696
	D	1940–41	.36	3.00	27.9	28	1619	1689	1649	1799	1431	1395
	E	1940–41	.34	2.90	21.6	27	1676	1782	1829	1973	1511	1592
K48	A	1939–42	.26	3.60	26.4	65	1151	1397	1378	1726	995	1185
	B	1938–42	.25	4.02	32.1	49	1209	1473	1375	1621	982	1186
	C	1938–42	.28	3.92	33.3	42	1236	1448	1333	1557	1049	1212
	D	1938–42	.24	3.70	34.6	57	1008	1290	1157	1462	863	1081
	E	1939–42	.30	3.25	26.3	77	1246	1422	1404	1816	988	1124
B29	A	1938–42	.27	4.06	23.1	28	808	1037	1063	1213	761	938
	B	1938–42	.30	4.32	23.6	31	1133	1309	1328	1494	1079	1215
	C	1938–42	.20	2.38	11.5	76	532	875	1062	1468	477	749
	D	1938–42	.26	4.22	27.3	41	977	1223	1191	1411	931	112
	E	1938–42	.23	3.96	28.5	50	658	958	910	1178	631	826

* Plots arranged in table according to their position in each district.
† A—Trunk-ground ratio. B—Increase in trunk circumference.
C—Terminal length. D—Biennial bearing index.
O—No adjustment.
‡ All yields are expressed in terms of loose bushel boxes per acre.

APPENDIX—Continued

TABLE 9.—"SUMMARY" DATA FROM McINTOSH TREES—*Continued*

1	2	3	4	5	6	7	8	9	10	11	12	13
Plot no.*	Tree no.	Years averaged	A†	B†	C†	D†	Total yield‡, adjusted for				Profitable yield‡, adjusted for	
							O†	A†	AC†	ACD†	O†	A†
				cm.	cm.		boxes	boxes	boxes	boxes	boxes	boxes
B30	A	1938–42	.28	5.24	34.4	34	944	1156	1026	1208	816	979
	B	1938–42	.30	4.70	29.4	27	1050	1226	1165	1309	935	1071
	C	1938–42	.27	4.74	27.5	41	910	1139	1104	1324	769	946
	D	1938–42	.23	5.06	35.6	54	823	1123	976	1265	641	872
	E	1938–42	.28	5.16	35.4	42	996	1208	1064	1288	859	1022
B31	A	1938–42	.27	4.18	24.4	43	891	1120	1128	1358	836	1013
	B	1938–42	.29	4.54	24.1	41	1099	1293	1305	1525	990	1140
	D	1938–42	.23	4.88	32.1	53	784	1084	986	1270	709	940
B32	A	1938–42	.21	3.22	21.6	46	581	916	963	1209	537	795
	C	1938–42	.30	4.92	31.3	46	1040	1216	1129	1375	911	1047
	D	1938–42	.25	4.20	27.6	57	843	1107	1071	1376	780	984
	E	1938–42	.25	5.50	29.2	56	871	1135	1077	1377	759	963
B1	A	1939–42	.39	2.57	24.6	73	1151	1169	1175	1565	958	972
	B	1939–42	.41	2.80	26.8	59	1175	1157	1132	1448	988	974
	C	1939–42	.43	2.43	22.6	62	1094	1059	1092	1424	921	894
	D	1939–42	.37	2.17	19.4	65	1060	1113	1190	1538	927	968
	E	1939–42	.39	2.00	19.4	65	945	963	1040	1388	855	869
B34	A	1939–42	.38	2.17	23.8	75	1091	1126	1143	1544	982	1009
	B	1939–42	.44	2.92	27.5	78	1086	1016	981	1398	892	843
	C	1939–42	.40	2.85	25.3	83	1079	1079	1072	1516	952	952
	D	1939–42	.39	2.87	26.2	85	1068	1083	1066	1521	939	953
	E	1939–42	.39	2.92	26.9	94	1031	1049	1023	1526	878	892
B33	B	1939–42	.36	2.77	15.5	37	1149	1219	1350	1548	1072	1126
	C	1939–42	.40	2.67	19.2	60	1277	1277	1357	1678	1205	1205
	D	1939–42	.38	2.35	21.1	55	1531	1566	1620	1914	1441	1468
	E	1939–42	.38	3.32	23.3	42	1566	1601	1625	1849	1405	1432
B38	A	1938–41	.39	2.75	20.2	40	1089	1107	1173	1387	1272	1069
	B	1938–41	.39	2.75	18.0	63	1200	1218	1315	1652	1092	1106
	C	1938–41	.41	2.25	22.7	71	1229	1211	1243	1623	1111	1097
	D	1938–41	.44	3.10	20.2	19	1445	1375	1441	1543	1351	1297
	E	1938–41	.49	3.37	15.3	63	1047	888	1022	1359	977	855
B36	A	1939–42	.39	2.07	26.8	85	866	884	859	1314	832	846
	B	1939–42	.40	2.02	25.1	90	942	942	941	1422	902	902
	C	1939–42	.43	1.92	23.4	88	894	841	863	1334	845	804
	D	1939–42	.42	2.55	25.5	87	957	922	915	1380	929	902
	E	1939–42	.38	2.05	29.7	88	776	811	746	1217	740	767
B57	A	1939–42	.38	2.65	26.1	87	745	780	765	1230	708	735
	B	1939–42	.37	2.57	24.5	85	806	859	866	1321	769	810
	C	1939–42	.40	2.80	29.1	83	715	715	658	1102	661	661
	D	1939–42	.37	2.50	29.5	45	1059	1112	1050	1291	999	1040
	E	1939–42	.38	3.17	31.1	61	980	1015	931	1257	920	947
G42	A	1939–42	.35	2.60	24.5	16	1580	1668	1675	1777	1368	1436
	B	1939–42	.36	2.92	27.1	10	1755	1825	1796	1849	1410	1464
	C	1939–42	.35	3.05	24.4	25	1369	1457	1465	1599	1145	1213
	D	1939–42	.30	2.77	27.3	42	1119	1295	1263	1487	927	1063
	E	1939–42	.33	2.35	25.3	23	1641	1765	1761	1884	1369	1464

* Plots arranged in table according to their position in each district.
† A—Trunk-ground ratio. B—Increase in trunk circumference.
C—Terminal length. D—Biennial bearing index.
O—No adjustment.
‡ All yields are expressed in terms of loose bushel boxes per acre.

APPENDIX—Continued

TABLE 9.—"SUMMARY" DATA FROM McINTOSH TREES—*Continued*

1	2	3	4	5	6	7	8	9	10	11	12	13
Plot no.*	Tree no.	Years averaged	A†	B†	C†	D†	Total yield‡, adjusted for				Profitable yield‡, adjusted for	
							O†	A†	AC†	ACD†	O†	A†
				cm.	cm.		boxes	boxes	boxes	boxes	boxes	boxes
G50	A	1939–42	.47	2.82	27.3	80	957	833	801	1229	810	715
	B	1939–42	.36	3.10	26.0	65	1076	1146	1132	1480	894	948
	C	1939–42	.39	2.90	27.6	67	1132	1150	1114	1472	957	971
	D	1939–42	.47	3.27	28.4	71	1188	1064	1017	1397	950	855
	E	1939–42	.46	3.10	23.9	76	1013	907	922	1328	839	758
G26	A	1939–42	.36	2.37	22.7	17	1211	1281	1313	1404	1055	1109
	B	1939–42	.31	1.55	26.6	23	1447	1606	1584	1707	1170	1292
	C	1939–42	.38	2.52	25.9	7	1792	1827	1815	1815	1484	1511
	D	1939–42	.29	2.12	22.0	19	1174	1368	1410	1512	993	1143
	E	1939–42	.36	1.40	24.8	10	1708	1778	1781	1834	1460	1514
G18	A	1939–42	.40	3.65	27.9	59	957	957	917	1227	727	727
	B	1939–42	.38	3.65	25.9	63	866	901	889	1226	685	712
	C	1939–42	.39	2.92	25.2	59	1149	1167	1164	1480	824	838
	D	1939–42	.40	3.40	22.4	61	1138	1138	1174	1500	842	842
	E	1939–42	.41	3.57	27.2	65	1012	994	964	1312	739	725
G17	A	1939–42	.29	1.77	20.2	74	787	981	1047	1443	722	872
	B	1939–42	.33	2.62	21.5	77	872	996	1044	1456	810	905
	C	1939–42	.24	1.42	20.4	73	751	1033	1097	1487	703	921
	E	1939–42	.33	1.90	16.4	80	781	905	1024	1452	730	825
G19	B	1939–42	.35	2.47	25.1	18	1191	1279	1278	1374	1043	1111
	C	1939–42	.35	2.17	20.0	45	956	1025	1266	1266	782	850
	D	1939–42	.36	2.37	21.2	30	1128	1198	1251	1411	1056	1110
G20	A	1939–42	.31	2.05	22.5	50	1296	1455	1605	1873	1188	1310
	B	1939–42	.32	2.32	24.4	29	1150	1291	1341	1496	1029	1238
	C	1939–42	.35	1.82	22.6	18	1175	1263	1381	1477	1065	1133
	D	1939–42	.34	1.25	18.8	20	1235	1341	1479	1586	1128	1209
	E	1939–42	.31	1.60	13.1	25	775	934	1147	1281	727	849
W2	A	1939–42	.35	2.62	20.5	30	842	930	992	1152	697	765
	B	1939–42	.34	2.25	21.7	34	830	936	982	1164	715	796
	E	1939–42	.32	1.82	16.4	16	1175	1316	1435	1521	1080	1299
W7	A	1939–42	.28	2.42	33.0	15	781	993	882	962	655	818
	B	1939–42	.34	2.00	25.5	18	1018	1124	1117	1213	847	928
	C	1939–42	.29	1.82	24.9	17	895	1089	1090	1181	739	889
	D	1939–42	.33	1.60	24.7	20	914	1038	1042	1149	774	869
	E	1939–42	.31	3.10	32.1	14	578	737	639	714	484	606
W6	B	1939–42	.32	2.32	26.8	75	775	916	891	1292	715	924
	C	1939–42	.29	1.42	19.4	36	660	854	931	1123	636	786
	D	1939–42	.29	1.87	25.2	32	763	957	954	1125	696	846
W5	C	1940–41	.30	1.80	20.6	21	1212	1388	1449	1561	993	1129
	E	1940–41	.32	1.50	16.3	35	994	1135	1255	1442	813	1022

* Plots arranged in table according to their position in each district.

† A—Trunk-ground ratio. B—Increase in trunk circumference.
C—Terminal length. D—Biennial bearing index.
O—No adjustment.

‡ All yields are expressed in terms of loose bushel boxes per acre.

APPENDIX—Concluded

TABLE 9.—"SUMMARY" DATA FROM McINTOSH TREES—*Concluded*

1	2	3	4	5	6	7	8	9	10	11	12	13
Plot no.*	Tree no.	Years averaged	A†	B†	C†	D†	Total yield‡, adjusted for				Profitable yield‡, adjusted for	
							O†	A†	AC†	ACD†	O†	A†
				cm.	cm.		boxes	boxes	boxes	boxes	boxes	boxes
W9	F	1939–42	.40	3.24	27.9	26	1512	1512	1472	1610	1086	1086
	G	1939–42	.34	2.72	28.3	21	1361	1467	1421	1533	1120	1201
	H	1939–42	.44	3.52	31.2	28	1689	1619	1533	1683	1289	1235
	I	1939–42	.37	2.99	31.7	23	1589	1642	1549	1672	1160	1201
	J	1939–42	.43	3.32	28.8	13	1680	1627	1574	1643	1402	1361
	K	1939–42	.37	2.92	29.3	8	1580	1633	1574	1617	1322	1363
W8	F	1939–42	.34	2.95	25.8	20	1547	1653	1642	1749	1020	1101
	G	1939–42	.39	3.56	29.3	12	1520	1538	1479	1543	1269	1283
	H	1939–42	.33	2.81	24.4	18	1183	1307	1315	1411	1038	1133
	I	1939–42	.38	3.38	28.0	10	1498	1533	1491	1544	1287	1314
	J	1939–42	.30	2.38	26.0	10	1153	1329	1315	1368	999	1135
	K	1939–42	.35	2.98	28.6	2	1468	1556	1506	1517	1248	1316
W10	F	1939–42	.47	1.61	26.1	34	1555	1431	1409	1591	1350	1255
	G	1939–42	.44	1.41	25.5	31	1338	1268	1261	1427	1180	1126
	H	1939–42	.47	1.82	25.1	29	1665	1541	1540	1695	1435	1340
	I	1939–42	.47	1.59	24.5	26	1448	1324	1331	1469	1265	1170
O14	A	1938–42	.36	2.94	24.2	24	968	1039	1048	1177	935	989
	B	1938–42	.35	2.96	24.8	29	1285	1373	1376	1531	1113	1181
	C	1938–42	.40	3.40	22.2	16	1327	1327	1366	1452	1200	1200
	D	1939–42	.39	2.40	20.7	4	1447	1465	1556	1577	1326	1340
	E	1938–42	.39	2.86	23.8	27	1153	1171	1188	1332	1050	1064
O17	A	1939–42	.32	2.62	23.8	75	836	977	994	1395	732	941
	B	1939–42	.36	3.27	24.2	78	980	1050	1061	1478	878	932
	C	1939–42	.37	2.87	25.7	65	875	928	918	1266	788	829
	D	1939–42	.38	2.87	28.5	62	1017	1052	1004	1336	884	911
	E	1939–42	.33	2.60	23.5	81	972	996	1017	1451	775	870
O15	A	1939–42	.27	3.82	35.7	38	799	1028	880	1083	565	742
	B	1939–42	.26	3.25	34.6	27	986	1232	1099	1243	799	989
	C	1939–42	.32	2.57	36.3	28	1126	1267	1111	1261	860	1069
	D	1939–42	.27	2.95	31.3	13	981	1210	1123	1192	829	1006
	E	1939–42	.24	2.85	29.5	37	889	1171	1109	1307	806	1024
O19	A	1938–41	.36	1.60	16.4	73	906	976	1095	1485	761	815
	B	1938–41	.37	1.45	13.7	49	819	872	1028	1290	619	660
	C	1938–41	.35	1.57	13.1	70	871	959	1124	1498	721	789
	D	1938–41	.36	1.67	13.1	70	832	907	1072	1446	698	752
	E	1938–41	.37	1.45	17.0	24	872	925	1036	1164	786	827

* Plots arranged in table according to their position in each district.

† A—Trunk-ground ratio. B—Increase in trunk circumference.
C—Terminal length. D—Biennial bearing index.
O—No adjustment.

‡ All yields are expressed in terms of loose bushel boxes per acre.

BOOK REVIEW

THE CATTLE OF BRITAIN. By Frank H. Garner, Cambridge University. 158 pages, 60 figs. Longmans, Green & Co., 215 Victoria St., Toronto 1, Ont. 1944. Price $5.50.

Practically all of the breeds of cattle which have been utilized in developing the cattle industry of Canada had their origin in Great Britain. Since this is the case, it is a matter of special interest to Canadians that a new book *The Cattle of Britain*, by a British authority, has just been published. The author is Frank H. Garner, Lecturer in Agriculture at Cambridge University and for some time Agricultural Organizer in East Suffolk.

This book may well serve in a dual rôle, namely, as a handbook for cattle raisers and as a text-book or reference for animal husbandry students in Colleges or Schools of Agriculture. The subject of cattle production under the conditions prevailing in Great Britain is treated in an essentially practical manner; the best in British practices has been sorted out and the methods discussed in a very readable style.

The forepart of the book is devoted to a historical account of the development of the cattle industry of Great Britain, including some comment on the work of early improvers, the formation of breeds, agricultural shows and other such matters. The importance of cattle raising in the agricultural pattern of Britain is then discussed. A considerable section concerns itself with certain general problems of cattle management, including a consideration of some of the common ailments and pests. Beef cattle, dairy cattle, and dual purpose cattle are each dealt with in turn; the breeds common to Britain are described and methods appropriate to the various types of cattle production are outlined.

The concluding chapter of *The Cattle of Britain* brings us up to date on the effects of the war on the cattle industry of Breat Britain. Of special interest is an account of the steps which have been taken to improve the quantity and quality of the milk supply and the effect of the ploughing-up campaign on methods of beef production.

The book carries sixty excellent illustrations displayed on glossy paper. Included is a pen drawing of the Smithfield Show Champion in 1873 (24 cwt. at 4 years of age).

R. D. SINCLAIR.